

LWCSIM Calibration and Application

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Agenda

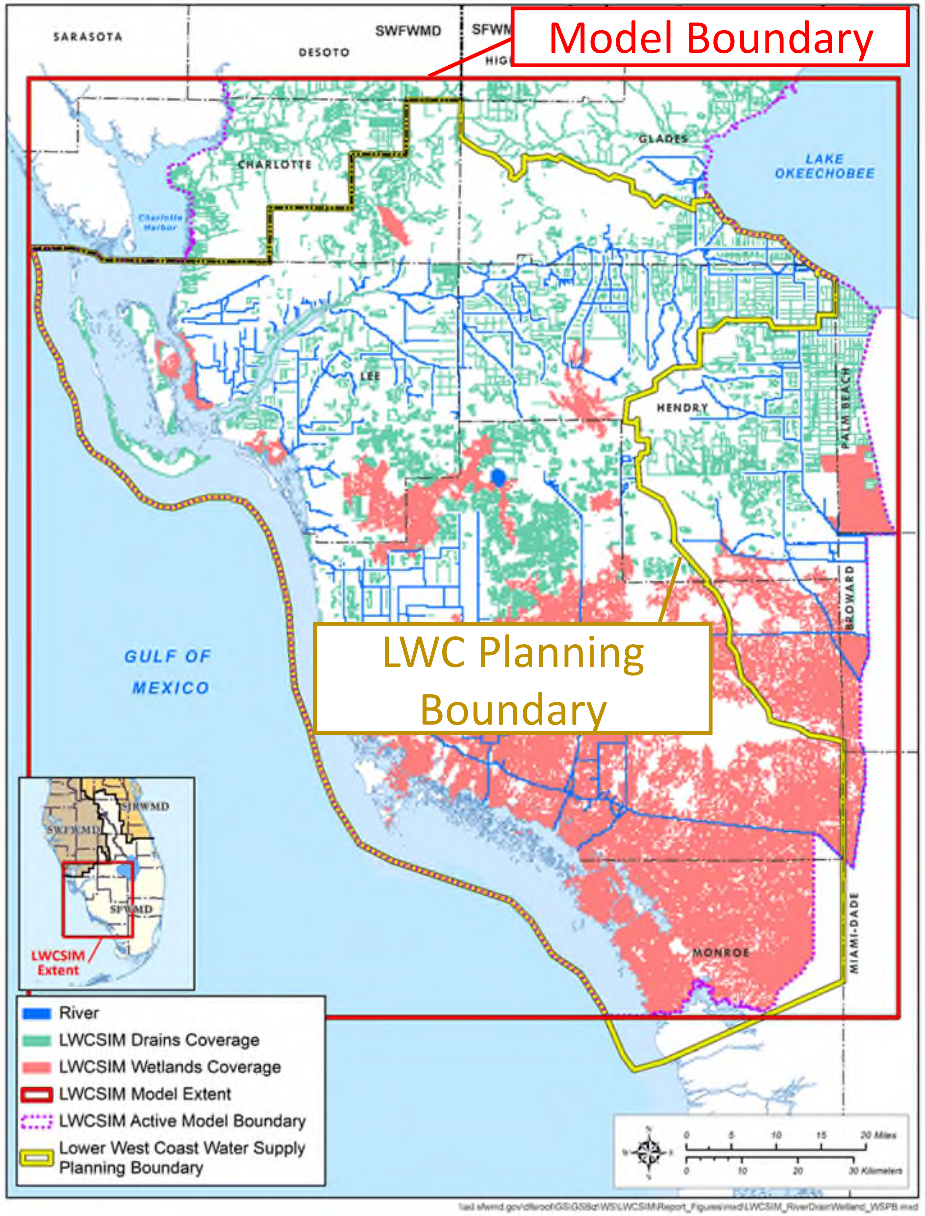
- Model objectives and overview
- Model calibration
- Model application
  - 2014 reference condition and 2040 future condition
  - Head difference maps (2014 and 2040)
  - Wetland impact analysis
  - Maximum developable limit (MDL) analysis
  - Velocity vectors analysis
- Conclusions

Model Objectives

- **Primary objective**: Support the Lower West Coast (LWC) water supply plan

- Tool will be used to evaluate if current and future groundwater withdrawals are sustainable
  - Identify areas where there is the potential for cumulative water use withdrawals to cause harm to wetlands and ground water resources
  - Identify potential for saltwater intrusion issues in coastal aquifers

Model Overview



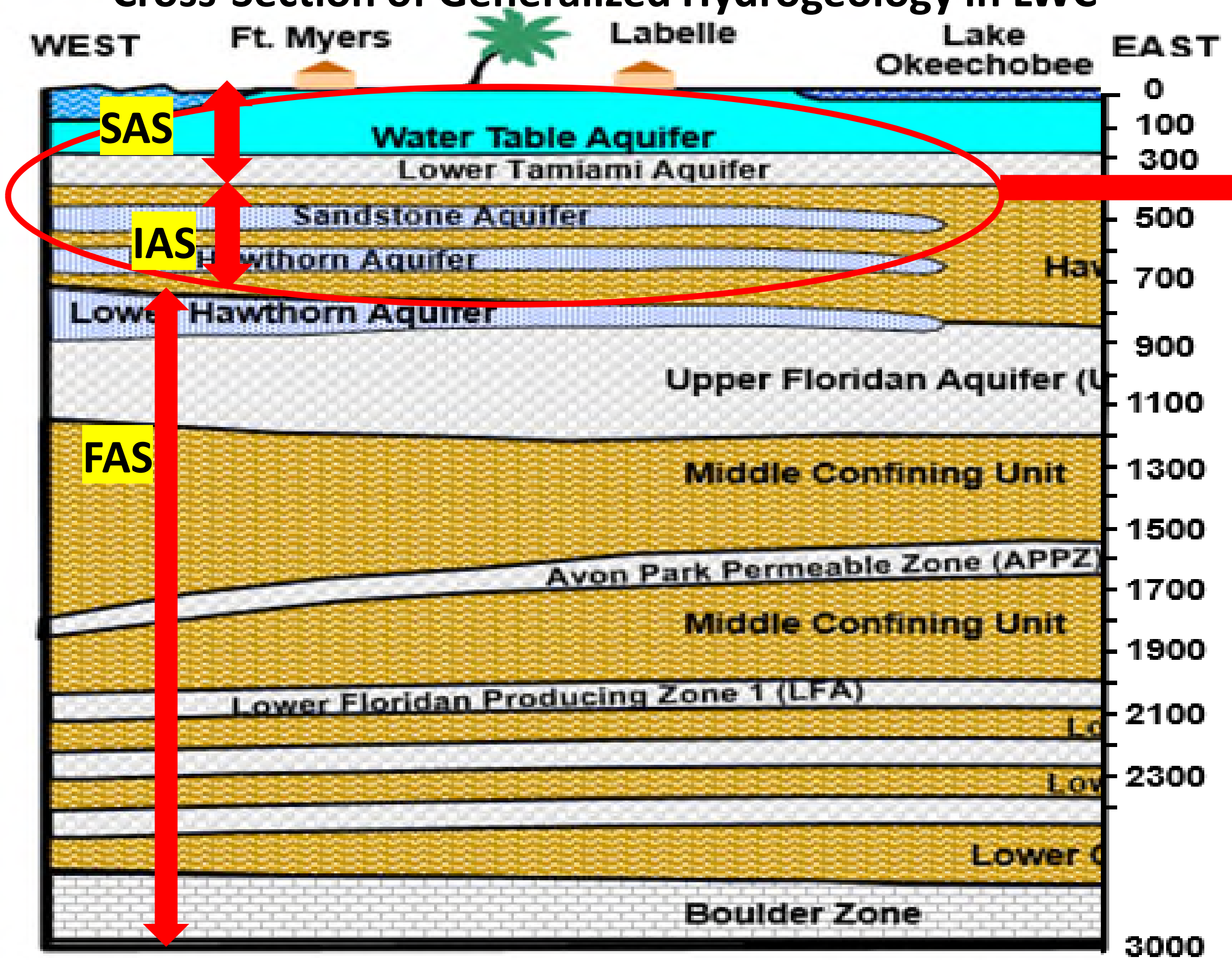
- Includes all of Lee, Collier, and Hendry counties and portions of Charlotte, Glades, and Monroe counties
- **Western boundary** coincides with the Gulf of Mexico and Peace River, including Pine Island and Sanibel Island
- **Eastern boundary** aligned with District's primary canal (north-south) and Lake Okeechobee
- **Southern boundary** coincides with Lostman's River and Big Lostman's Bay tidal boundaries
- **Northern boundary** specified head boundary, reasonable distance away from areas of interest

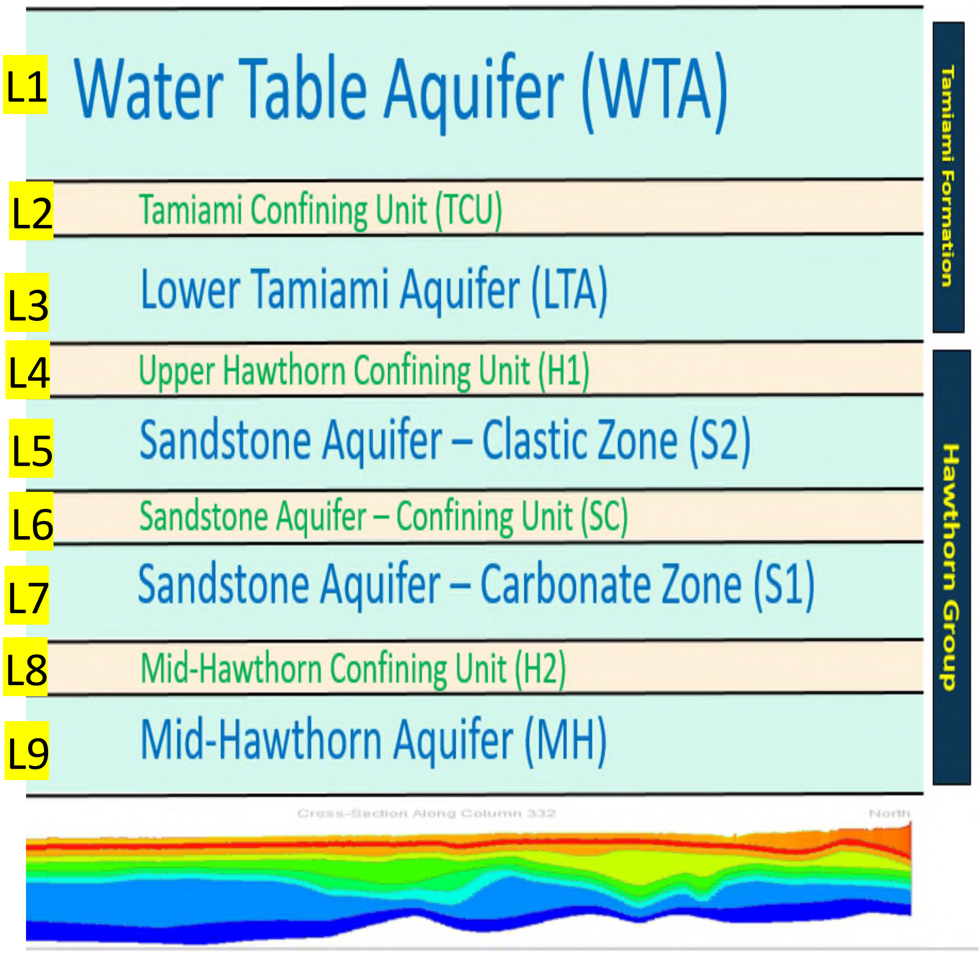
Model Overview (cont.)

- First SFWMD model for the surficial (SAS) and intermediate (IAS) aquifer systems for LWC planning region
- Used updated hydrostratigraphy for model layering
  - Recent SFWMD publication by Geddes et al. (2015)
- MODFLOW based, uniform grid size of 1,000 ft × 1,000 ft
- Monthly stress periods (time varying data input interval)
- Reclaimed water incorporated through golf course and landscape irrigation return flows
- Calibration period: 1999-2012, verification period 2013-2014
- Calibrated for surface water flows/levels and groundwater levels
- Independent scientific peer review
  - Concurrent with model development
  - Panel: 3 experts in South Florida hydrogeology and groundwater modeling

Model Layers

Cross-Section of Generalized Hydrogeology in LWC





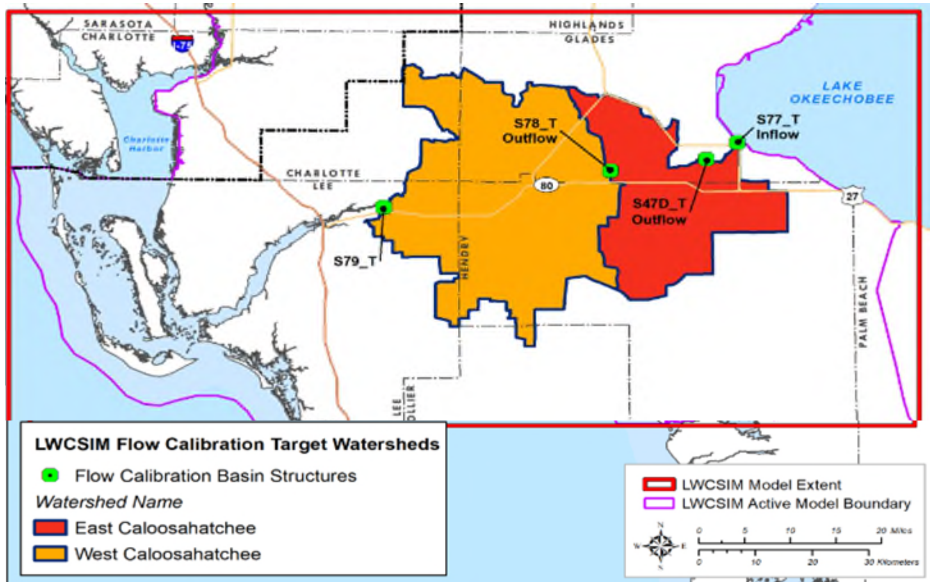
9 Layer model with 5 productive aquifers

SAS=Surficial Aquifer System; IAS=Intermediate Aquifer System; FAS=Floridan Aquifer System

Model Calibration

Surface Water Flow Calibration Summary

- Strong hydraulic connection between surface water and SAS in the LWC
- Ensure surface flows and stages are reasonable as they impact groundwater recharge
- Simple surface water and unsaturated zone model integrated with MODFLOW through evapotranspiration and recharge
- Calibrated simulated flows to observed structure flows at two major watersheds



Statistics	Criteria	Watershed	
		East Caloosahatchee	West Caloosahatchee
Deviation of Volume (DV)	< 15%	-9.30%	0.54%
Nash-Sutcliffe (NS)	> 0.5	0.55	0.54
R Squared (R2)	> 0.5	0.56	0.55

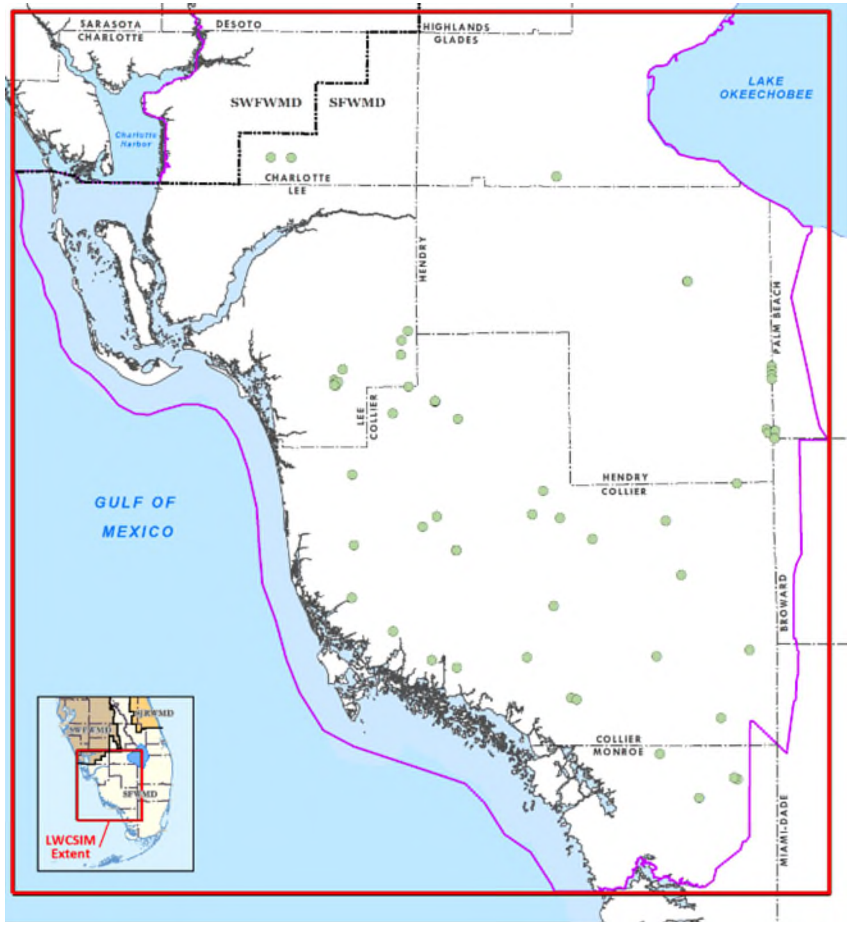
Green font indicates compliance with all calibration criteria

Calibration Criteria Established

- Peer-review recommendation
- Previous models

Surface Water (Wetland) Level Calibration Summary

- Overland flow simulation – wetlands package
  - 60 target wetland gauges



Green font indicates compliance with all calibration criteria

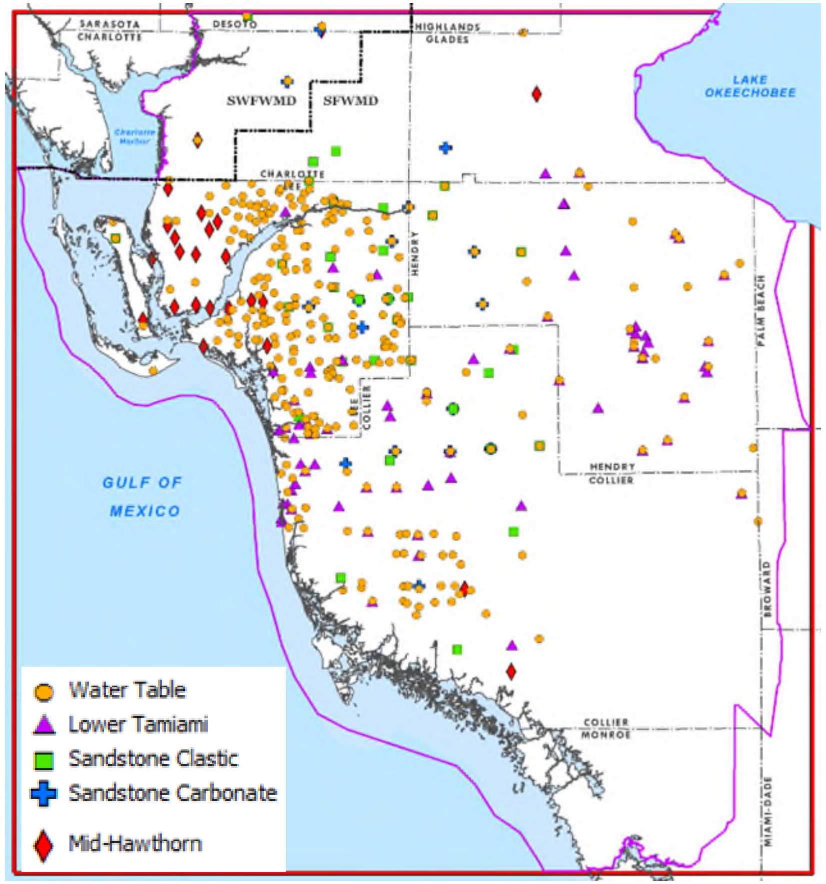
Calibration Period: 1999 - 2012

LWCSIM	Criteria	ft or %
Residual Mean	+/- 1 foot	-0.7
Error Standard Dev	< 5 ft	1.79
Absolute Residual Mean (MAE)	< 5 ft	1.64
RMS Error	< 5 ft	1.91
Minimum Residual		-9.12
Maximum Residual		6.45
Number of Observation Points		60
Percentage with MAE < 2.5 ft	> 50%	85
Percentage with MAE < 5.0 ft	> 80%	98
Percentage with R2 > 0.4	> 60%	63
Percentage with TNSE > 0	> 60%	63

Calibration criteria was based on previous models and peer-review recommendation

Groundwater Level Calibration Summary

- 441 target groundwater monitoring wells



Green font indicates compliance with all calibration criteria

Calibration period 1999 - 2012

Statistics	Criteria	Aquifer				
		WTA	LTA	S2	S1	MH
Residual Mean	+/- 1 foot	-0.34	0.51	0.7	0.98	-0.85
Error Standard Dev	< 5 feet	2.27	2.97	3.22	1.8	3.21
Absolute Residual Mean (MAE)	< 5 feet	1.76	2.44	2.38	1.68	2.55
RMS Error	< 5 feet	2.29	2.99	3.24	2.01	3.25
Minimum Residual		-9.12	-4.12	-9.91	-3.28	-7.38
Maximum Residual		6.45	9.35	5.27	3.78	4.39
Number of Observation Points		297	72	29	18	25
Percentage with MAE < 2.5 ft	> 50%	73	61	62	72	56
Percentage with MAE < 5.0 ft	> 80%	97	96	90	100	88
Percentage with R2 > 0.4	> 60%	75	81	76	83	64
Percentage with TNSE > 0	> 60%	72	85	83	94	64

Calibration criteria was based on previous models and peer-review recommendation

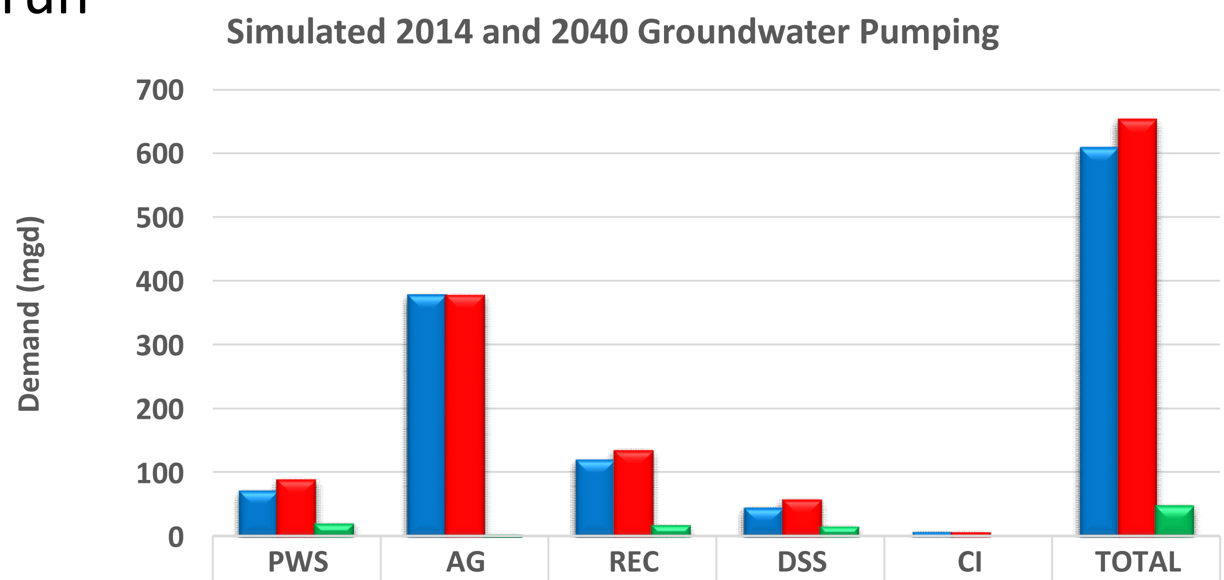
Model Application

Model Application

- Reference condition (2014) and future condition (2040) runs
  - Similar simulation period to calibration run (16 years)
  - Similar climatic conditions to calibration run
  - New pumping values

Type	2014 Method	2040 Method
Public Water Supply (PWS)	Reported	Projected
Agricultural (AG)	Estimated*	Projected
Recreational (REC)	Estimated*	Projected
Domestic Self Supplied (DSS)	Estimated**	Projected
Commercial-Industrial (CI)	Permitted	Permitted

Increased demands were assigned to existing wells for PWS, added additional wells for AG and REC within the permit boundary, and used locations identified in population projections for DSS

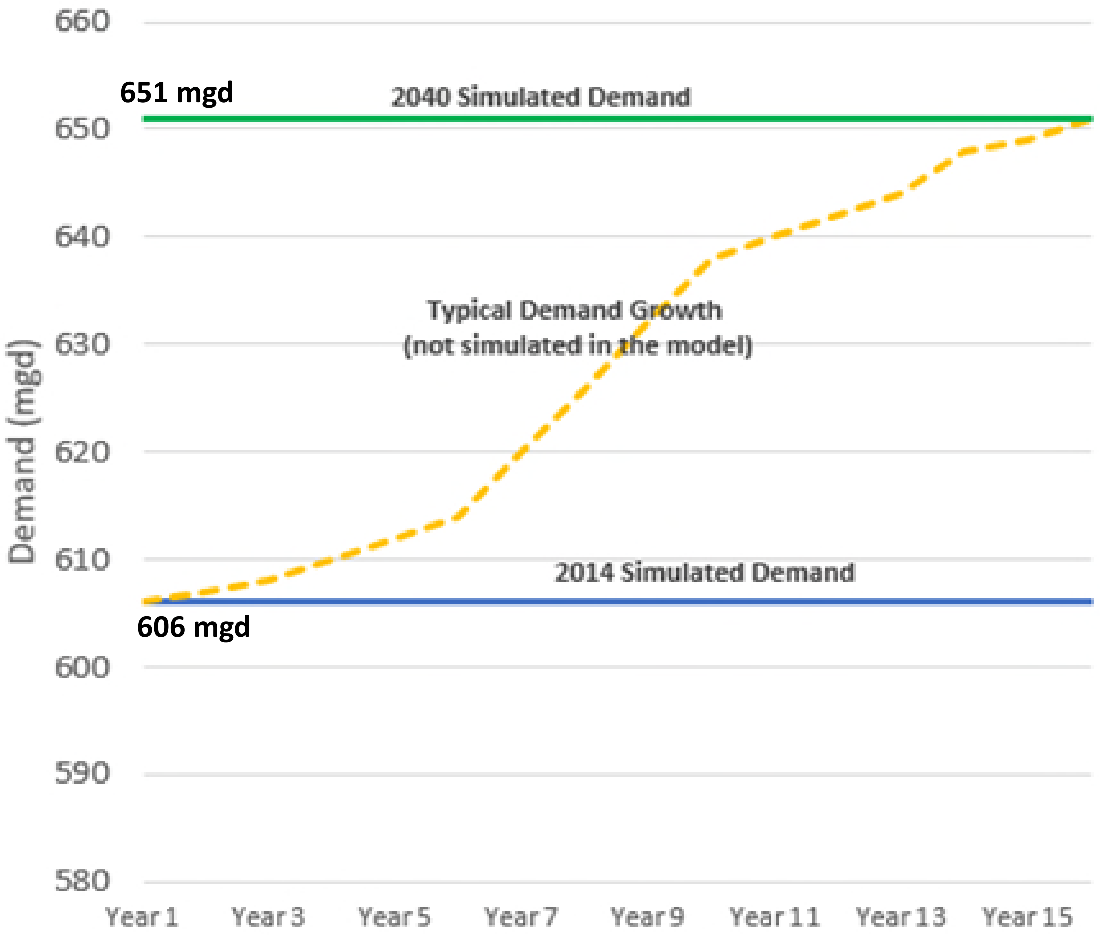


	PWS	AG	REC	DSS	CI	TOTAL
2014 (mgd)	68	376	117	42	3	606
2040 (mgd)	86	376	132	55	3	651
Diff (mgd)	18	0	15	13	0	45

*AFSIRS = Agricultural Field Scale Irrigation Requirement Simulation
**County Level Per Capita Use

Limitation in 2040 Simulation

- Simulated demands are “instant on”
- Demands do not include annual growth
- Results from the 2040 simulation are considered conservative

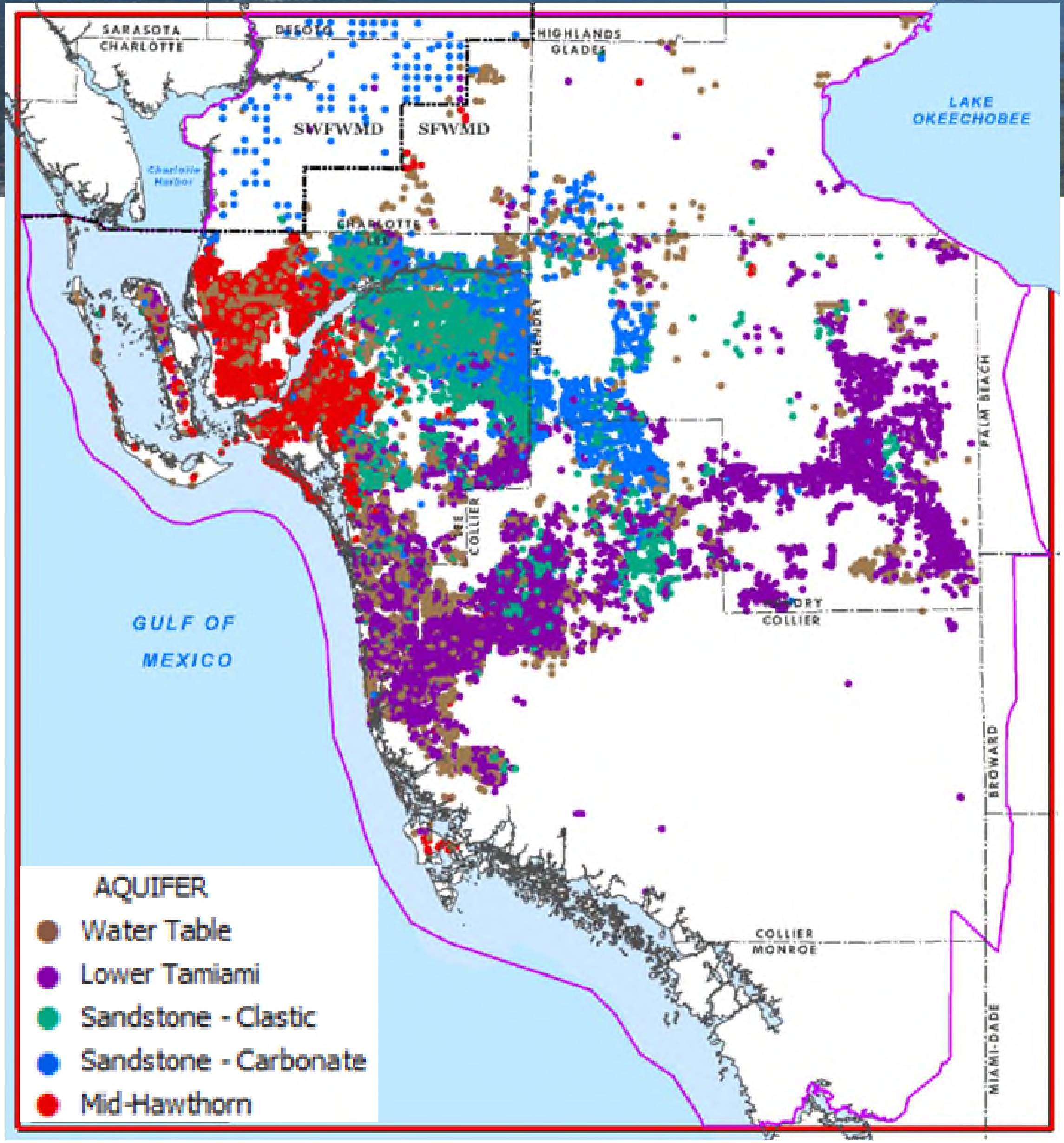


Raw water demand shown for all use types

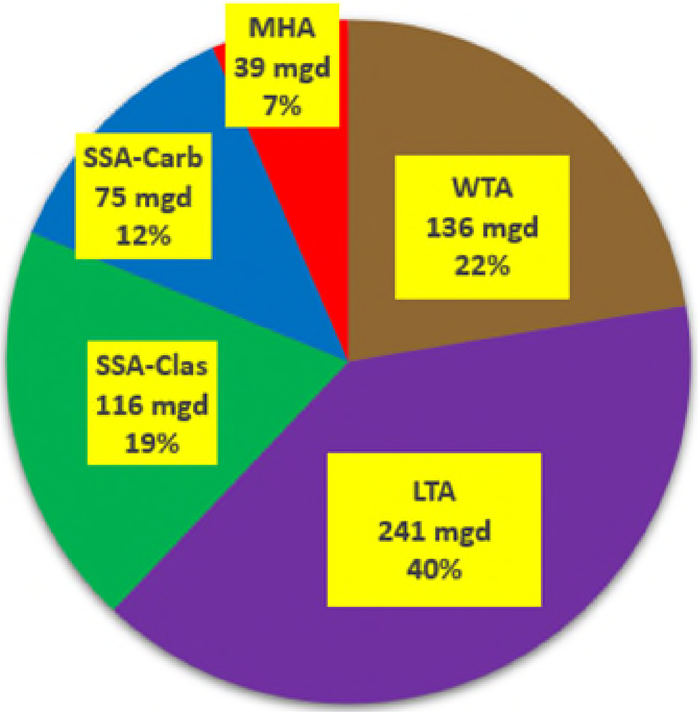
Regional Model Limitations

- Heterogeneity
  - Regional model (1,000 ft × 1,000 ft cell) may not capture local variability in aquifer properties or responses at individual wells
- Multiple wells in a single model cell
  - Model aggregates all withdrawals at the center of the model cell
  - Tends to exaggerate water level drawdowns
  - Results are conservative
- Regional model results from simulations should be used as an overall planning tool and results should not be taken as absolutes

Pumping Wells in Model



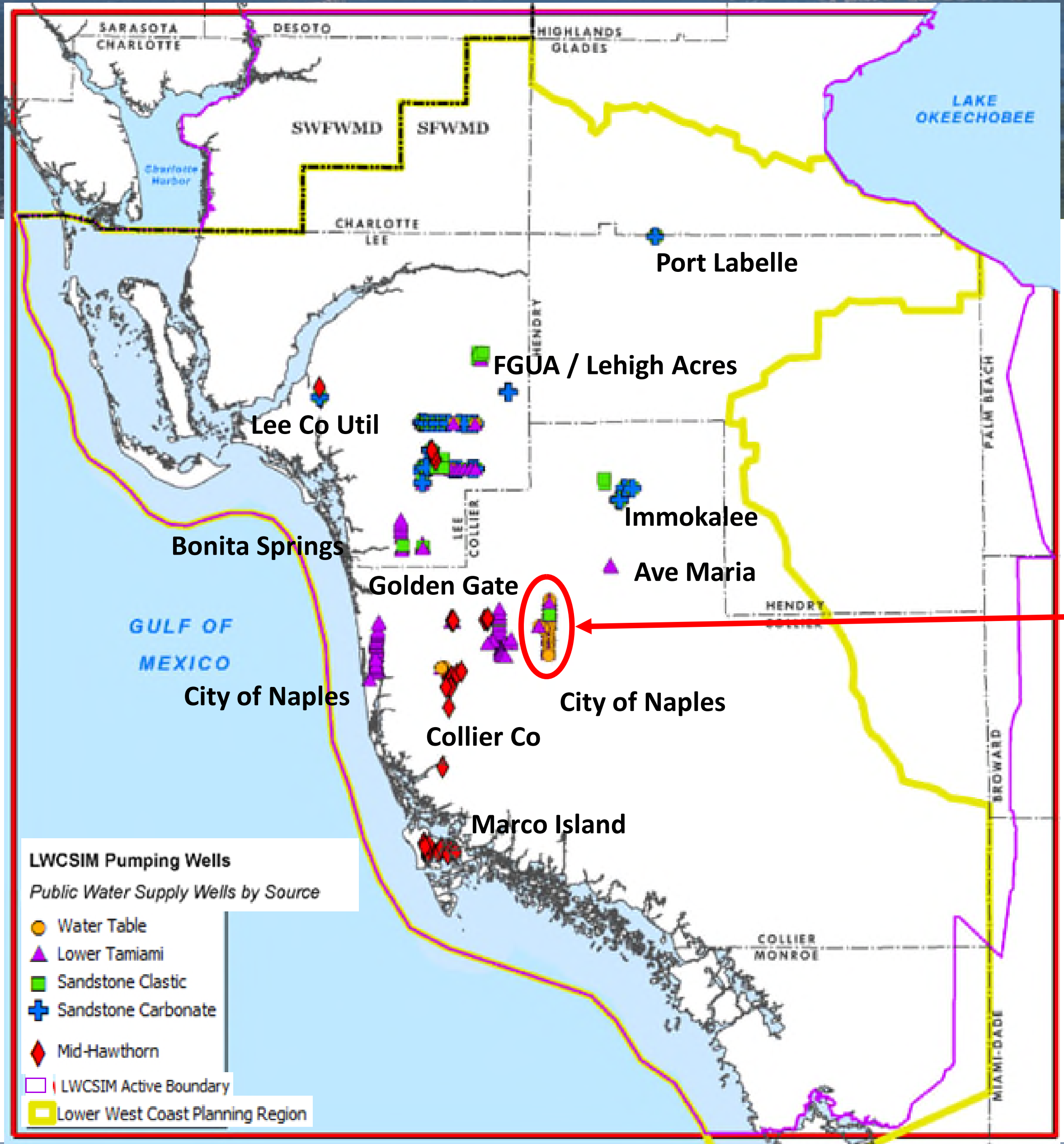
Pumped Volumes by Aquifer (2014)



Total Pumped = 606 mgd

WTA: Water Table aquifer
LTA: Lower Tamiami aquifer
SSA: Sandstone aquifer
MHA: Mid-Hawthorn aquifer

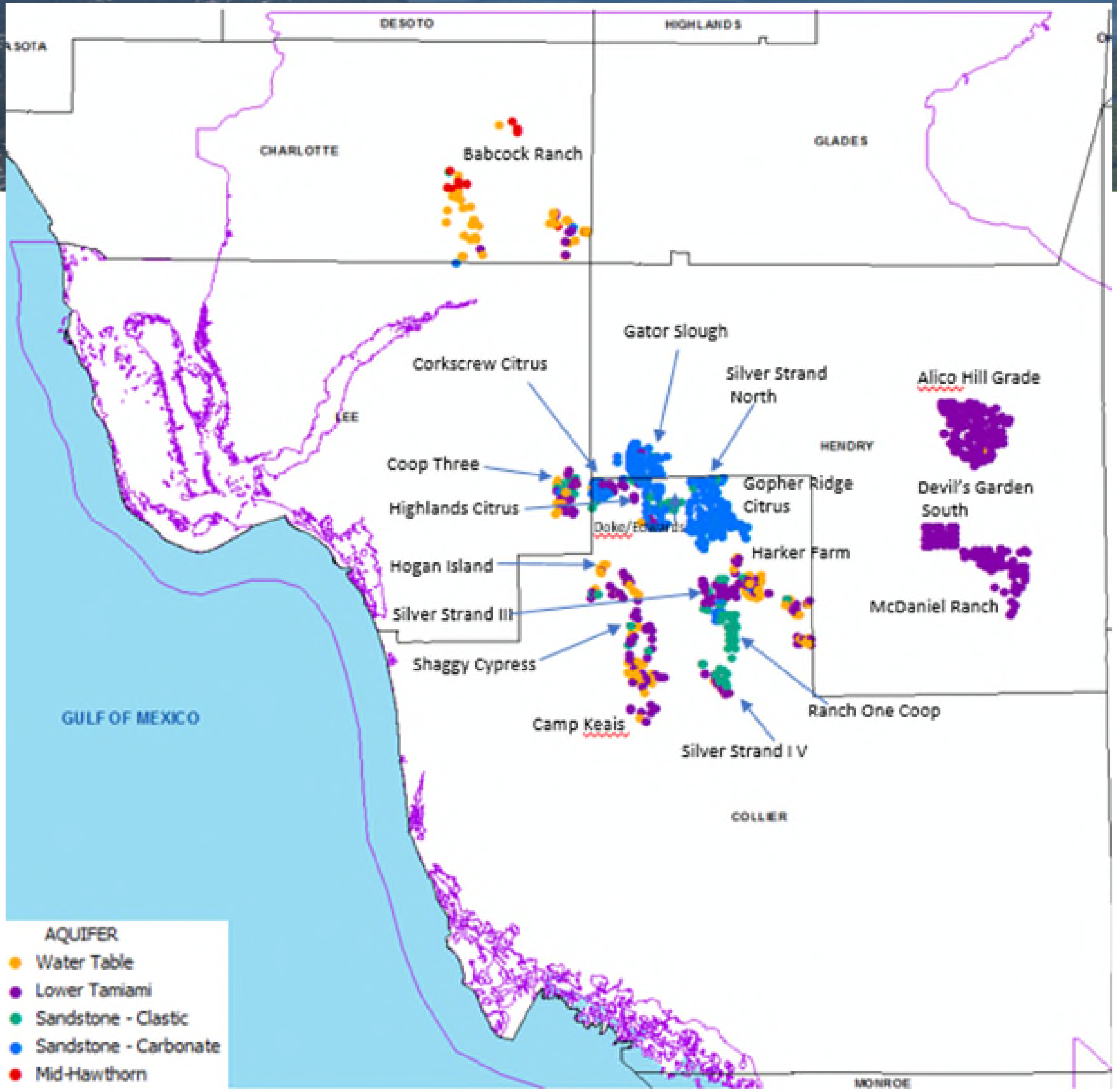
Largest Public Water Supply Permits in SAS/IAS



Lee			Projected	
Permittee	Current Allocation MGD	2014 Demand MGD	2040 Demand MGD	2040 - 2014 DIFF MGD
Lee Co. Util.Corkscrew/Green Meadows/Olga	34.27	13.74	16.24	2.50
Bonita Springs Utilities	5.74	3.53	5.48	1.95
FGUA –Lehigh Acres	3.15	2.06	3.46 *	1.40
Citrus Park RV Resort	0.23	0.19	0.24 *	0.05
Lee County Utilities - Pinewoods	7.36	1.76	1.80	0.04
FGUA – Lake Fairways	0.101	0.10	0.10	0.00
Collier				
Naples, City of – Utility Department	18.42	14.13	20.22 *	6.09
Collier County – N Regional, S Regional	53.5	23.77	25.80	2.03
Marco Island Utilities	13.16	1.85	3.62	1.76
Ave Maria Utility Company	1.16	0.30	2.01 *	1.71
Collier Golden Gate (fka FGUA)	2.5	1.64	0.00	-1.64
Immokalee Water & Sewer District	4.15	1.93	2.41	0.48
Collier County (fka Orange Tree)	0.65	0.42	0.87 *	0.45
Everglades City, City of	0.3	0.16	0.27	0.11
Port of the Islands CID	0.55	0.22	0.25	0.03
Hendry				
LaBelle, City of	1.06	0.36	0.01	-0.35
Port LaBelle Utility System	0.53	0.54	0.53	-0.01
Charlotte				
Town and Country Utilities Company	0.78	0.00	0.78	0.78
Charlotte Correctional	0.12	0.10	0.10	0.00

** Indicates a modeled demand over the current permitted allocation; however, it is not guaranteed to be permitted by SFWMD Water Use Bureau*

Largest Agricultural Permits



Charlotte			Projected	
Permittee	Allocation mgd	2014 Demand mgd	2040 Demand mgd	DIFF (2040-2014 mgd
Babcock Ranch	8.91	8.07	8.76	**0.69**
Collier				
Corkscrew Citrus	13.78	12.06	9.33	-2.73
Silver Strand I I I	8.05	5.07	4.12	-0.95
Ranch One Coop	9.36	7.30	8.01	0.71
Silver Strand North	11.48	11.06	10.38	-0.68
Highlands Citrus	7.70	4.32	3.74	-0.58
Harker Farm	12.16	10.88	10.35	-0.53
Gator Slough	16.25	13.65	14.17	0.52
Shaggy Cypress	13.43	5.40	4.92	-0.48
Silver Strand I V	6.06	6.00	5.65	-0.35
Hogan Island	10.52	5.09	5.43	0.34
Camp Keais Ag Dev	16.63	5.60	5.32	-0.28
Gopher Ridge Citrus	10.35	6.89	6.89	0.00
Hendry				
lico Hill Grade Combin	10.45	5.25	5.63	0.38
McDaniel Ranch	28.25	22.60	22.83	0.23
Devil's Garden South	7.64	6.01	6.07	0.06
Lee				
Cooperative Three Inc	7.54	1.81	1.69	-0.12

Model Results: Simulated Head (Water Level) Differences

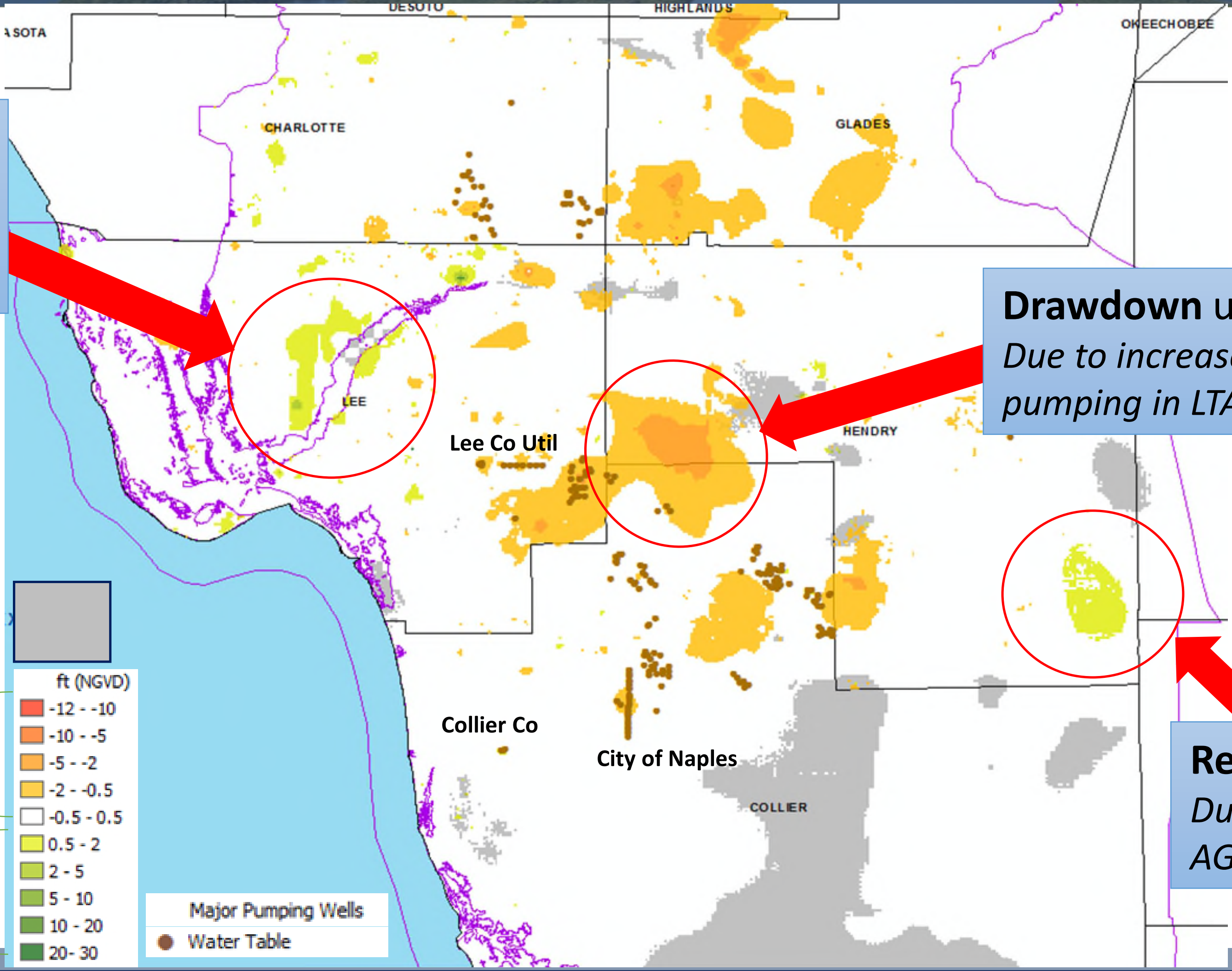
2040 Future Average – 2014 Reference Condition Average

Head Difference: Water Table Aquifer

2040 Future Average – 2014 Reference Condition Average

Rebound up to **1 ft**
Due to decline in 2040 DSS pumping in MHA. LTA and SSA are absent

Drawdown up to **3 ft**
Due to increase in AGR pumping in LTA and SSA



Aquifer absent

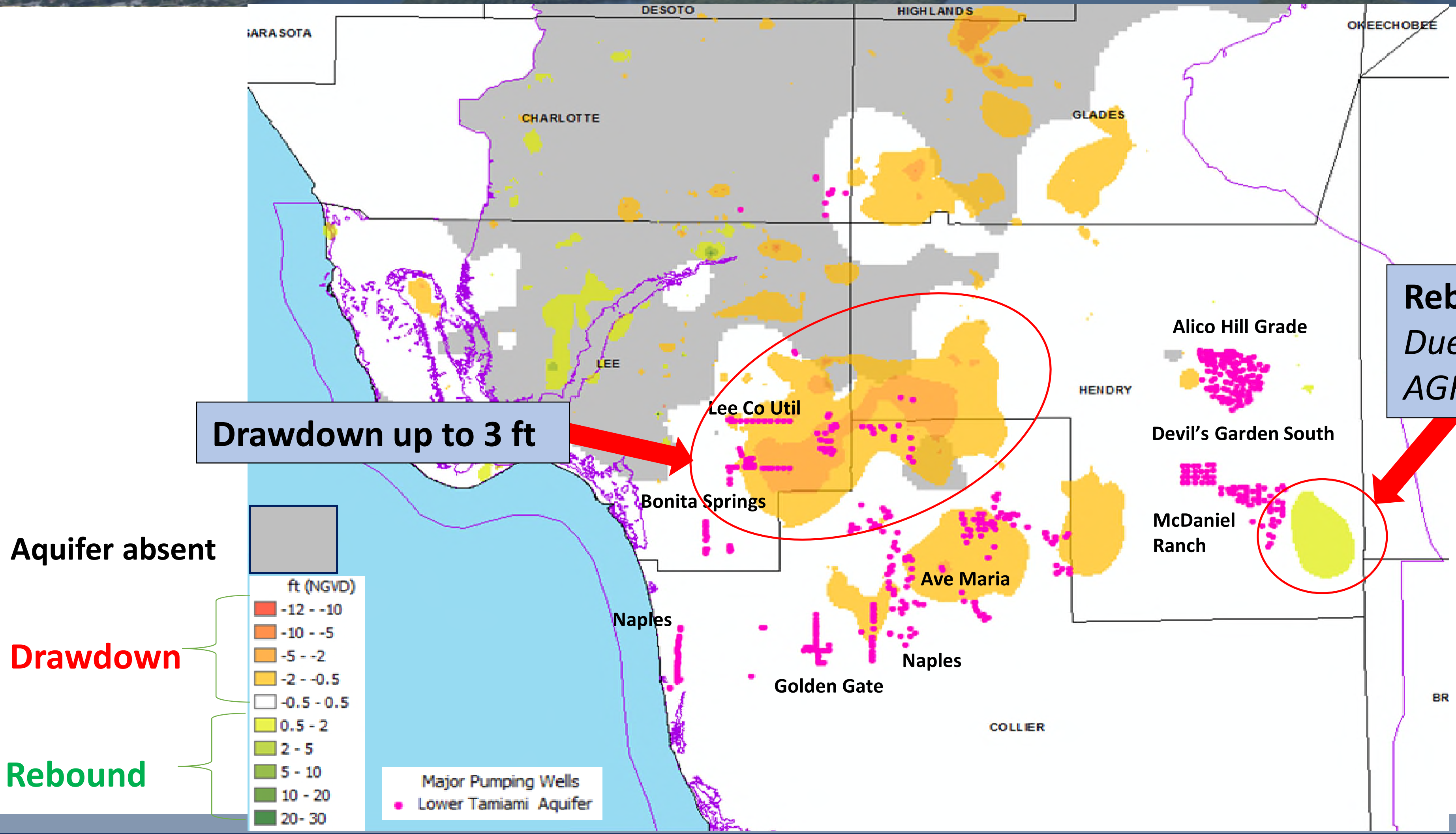
Drawdown

Rebound

Rebound up to **1 ft**
Due to decrease in LTA AGR pumping in 2040

Head Difference: Lower Tamiami Aquifer

2040 Future Average – 2014 Reference Condition Average



Drawdown up to 3 ft

Rebound up to 1 ft
Due to decrease in LTA AGR pumping in 2040

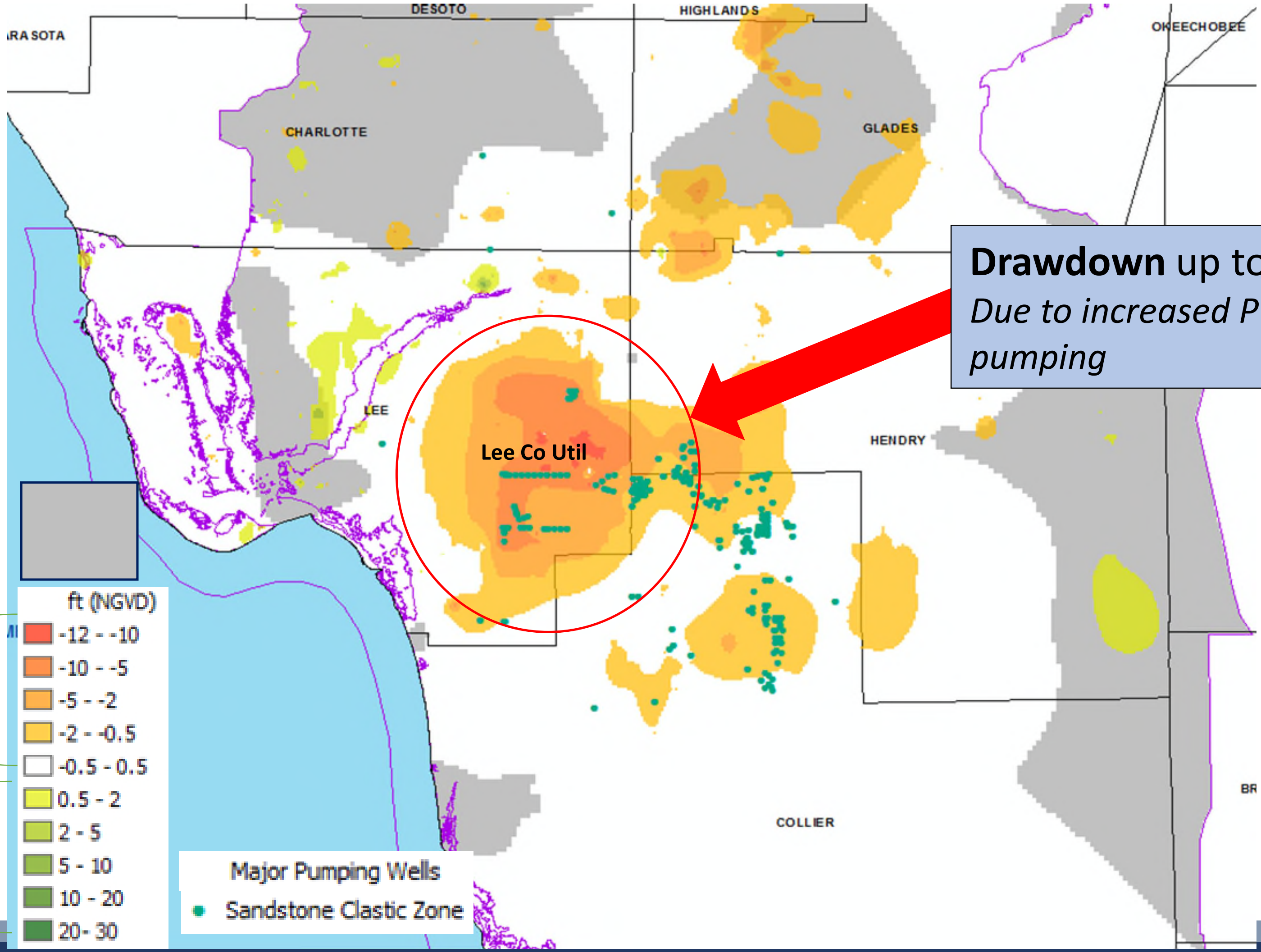
Head Difference: Sandstone-Clastic Aquifer

2040 Future Average – 2014 Reference Condition Average

Aquifer absent

Drawdown

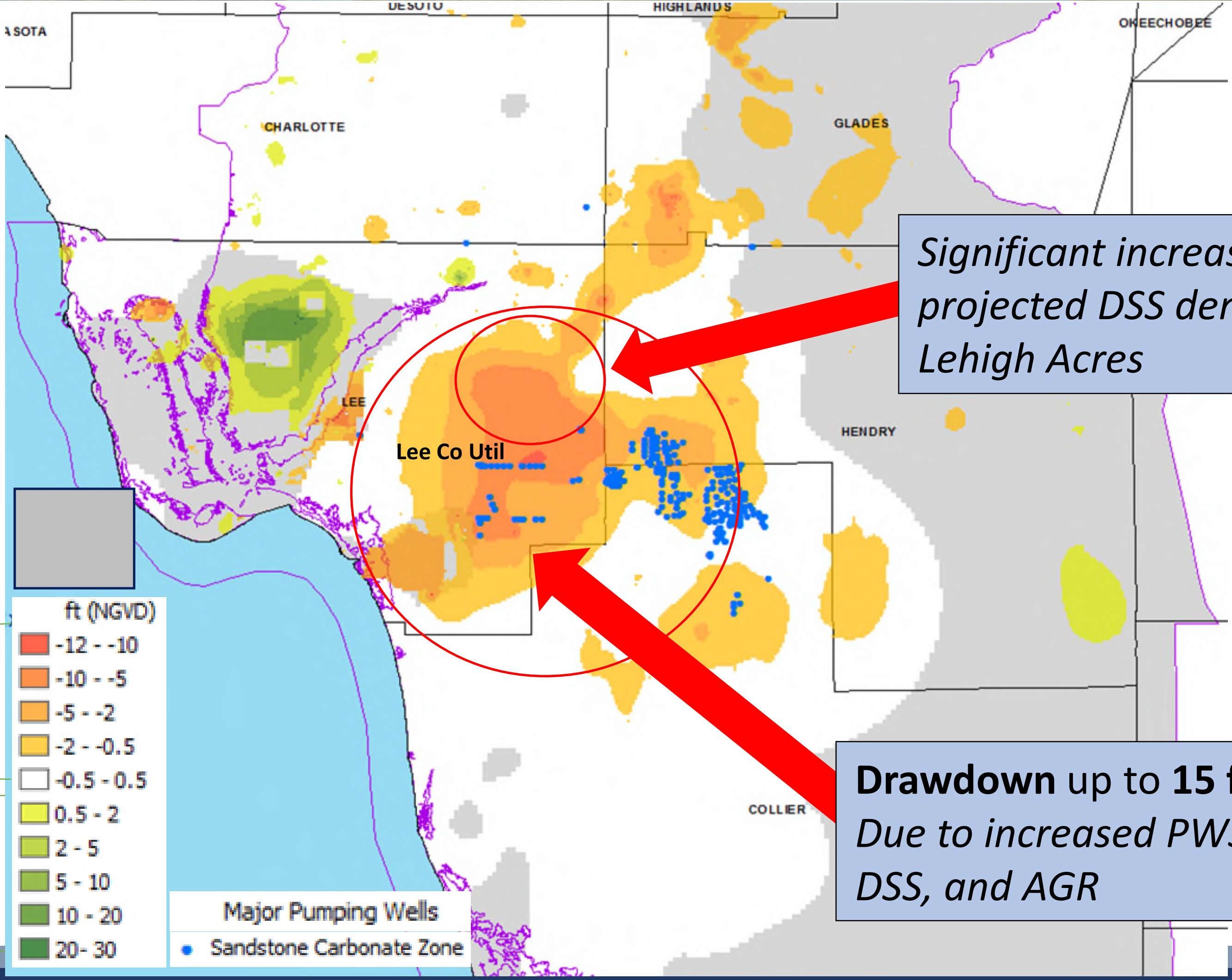
Rebound



Drawdown up to **12 ft**
Due to increased PWS and AGR pumping

Head Difference: Sandstone-Carbonate Aquifer

2040 Future Average – 2014 Reference Condition Average



Aquifer absent

Drawdown

Rebound

Significant increase in projected DSS demand in Lehigh Acres

Drawdown up to **15 ft**
Due to increased PWS, DSS, and AGR

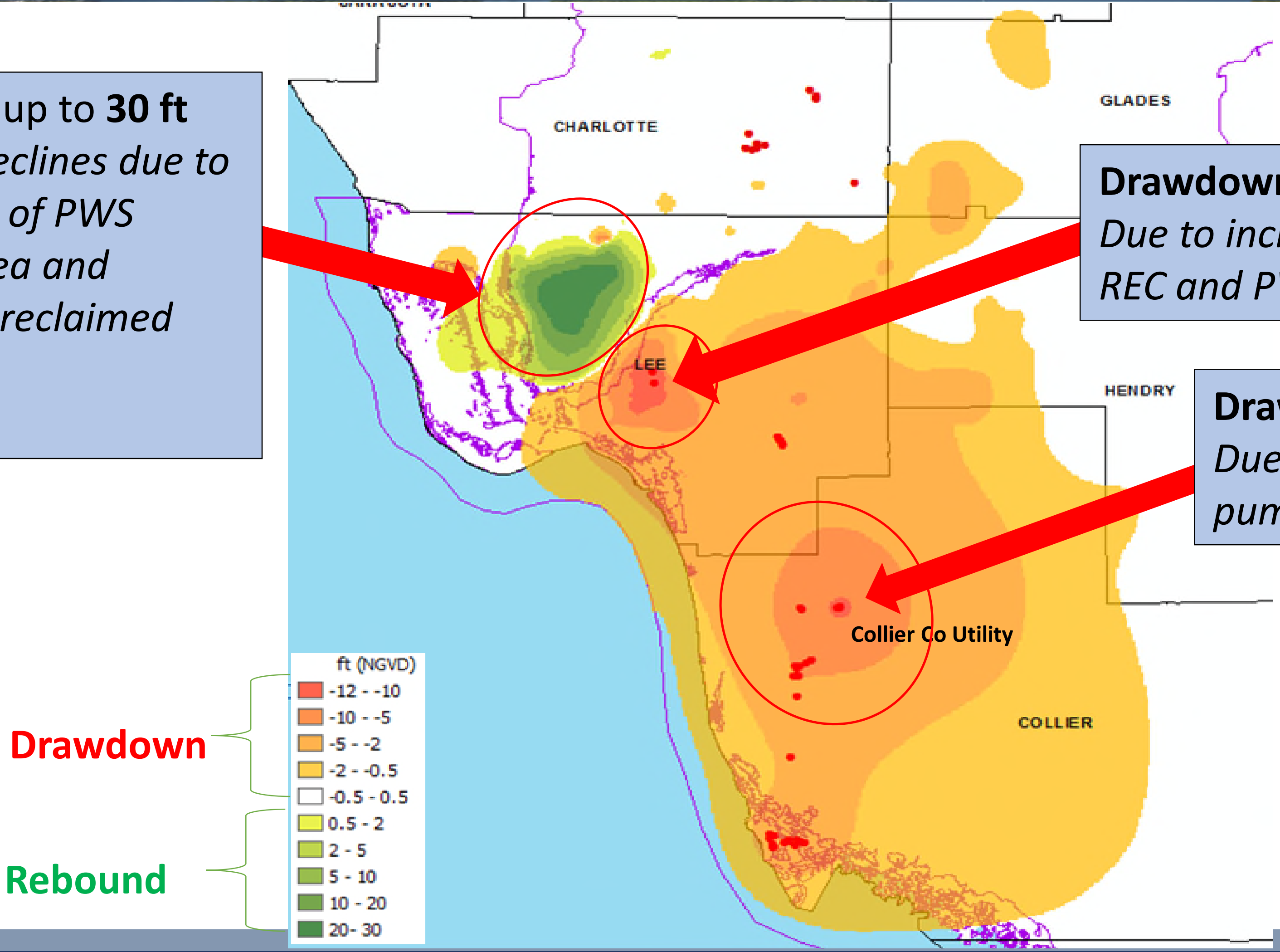
Head Difference: Mid-Hawthorn Aquifer

2040 Future Average – 2014 Reference Condition Average

Rebound up to **30 ft**
DSS use declines due to expansion of PWS service area and increased reclaimed water use

Drawdown up to **12 ft**
Due to increase in REC and PWS pumping in MHA

Drawdown up to **12 ft**
Due to increase in Collier Co. pumping in MHA



- MHA is not a very productive aquifer
- Higher drawdown responses even for smaller pumping



Wetland Impact Analysis (Pumps Off Scenario)

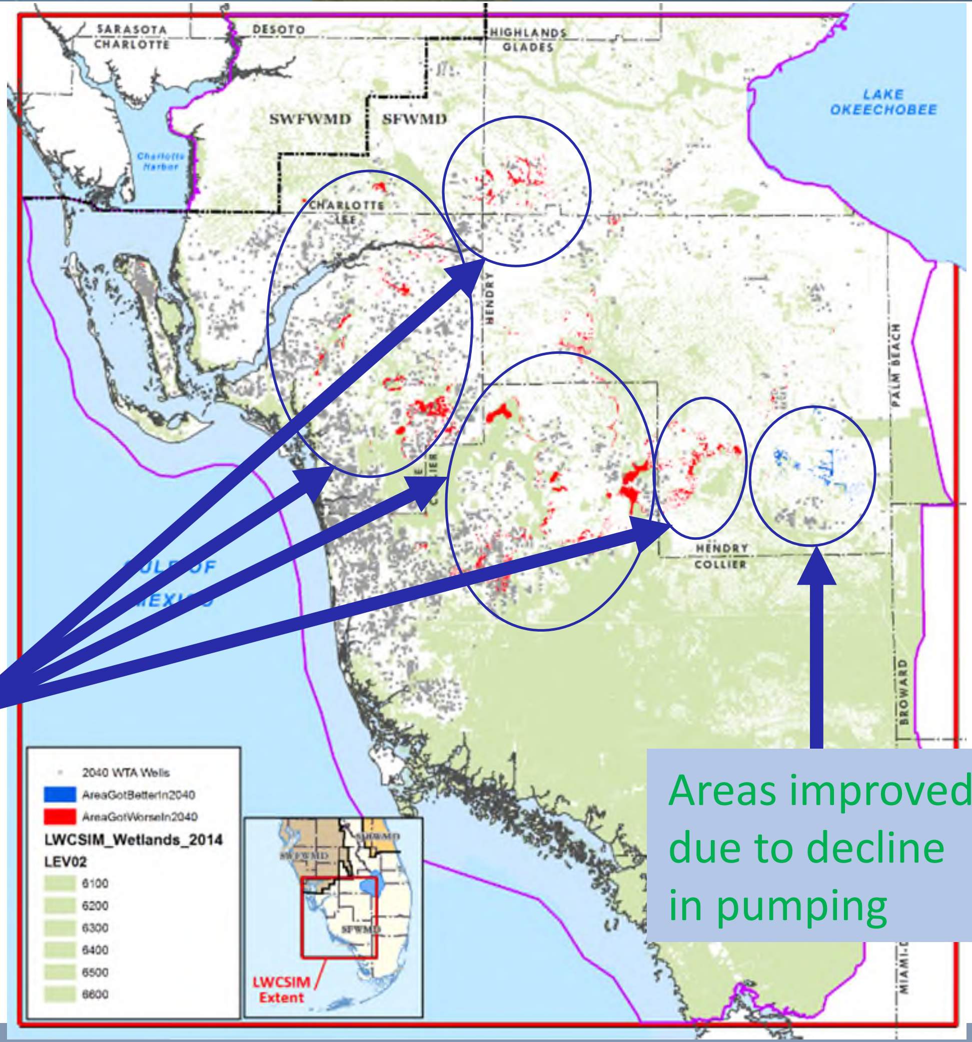
Pumps Off Heads Minus Pumps On Heads

- Purpose
  - To identify potential wetland areas that can be adversely affected by cumulative water use withdrawals
- Limitations
  - Model calibrated to boundary conditions with pumping occurring, not to extreme condition of no pumps
  - Effects of drainage and developments also negatively impact wetlands, but that is not part of this analysis

Wetland Impact Analysis

- Method
  - Use pumps off runs for 2014 reference condition and 2040 future condition and overlay the 2014 wetland land use
  - Identify wetland areas with a potential 1 ft or greater of additional drawdown in Water Table Aquifer
  - Note: Red areas are areas with 1 ft or greater of additional drawdown underlain by wetlands

Areas exceeding screening criteria



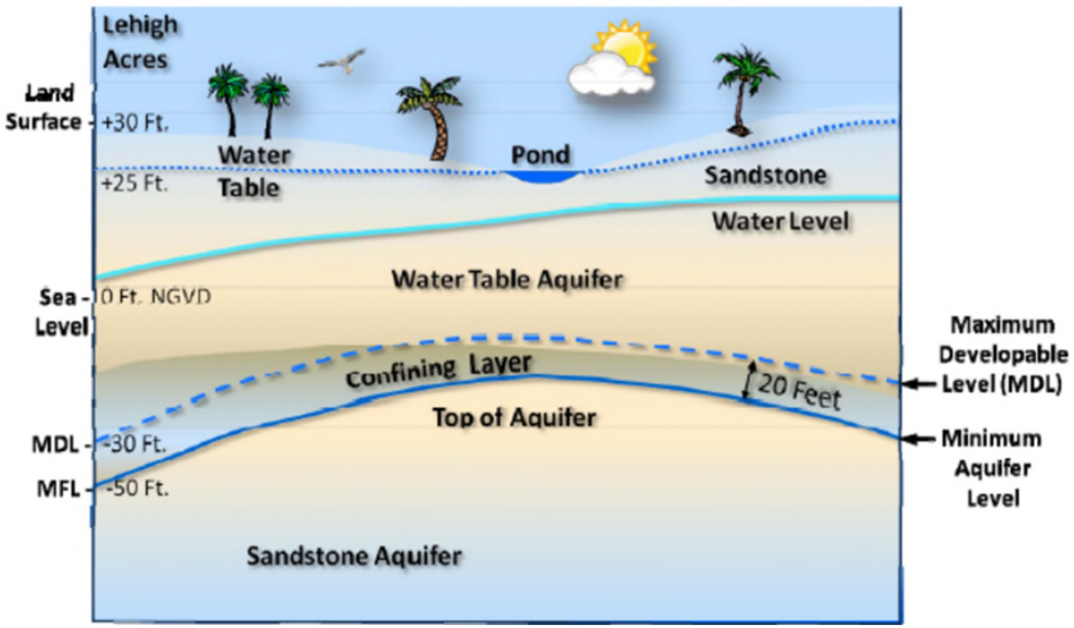
Areas improved due to decline in pumping

Maximum Developable Limit Analysis

Maximum Developable Limit (MDL) Analysis

- MDLs are part of Minimum Flow Level (MFL) prevention strategy that prevent harmful withdrawals from the following aquifers:
  - Lower Tamiami
  - Sandstone
  - Mid-Hawthorn
- MDLs prohibit water withdrawals that lower the water levels less than 20 ft above the top of the uppermost geologic strata of the aquifer at any point during a 1-in-10 year* drought condition

Sandstone Aquifer MDL Example

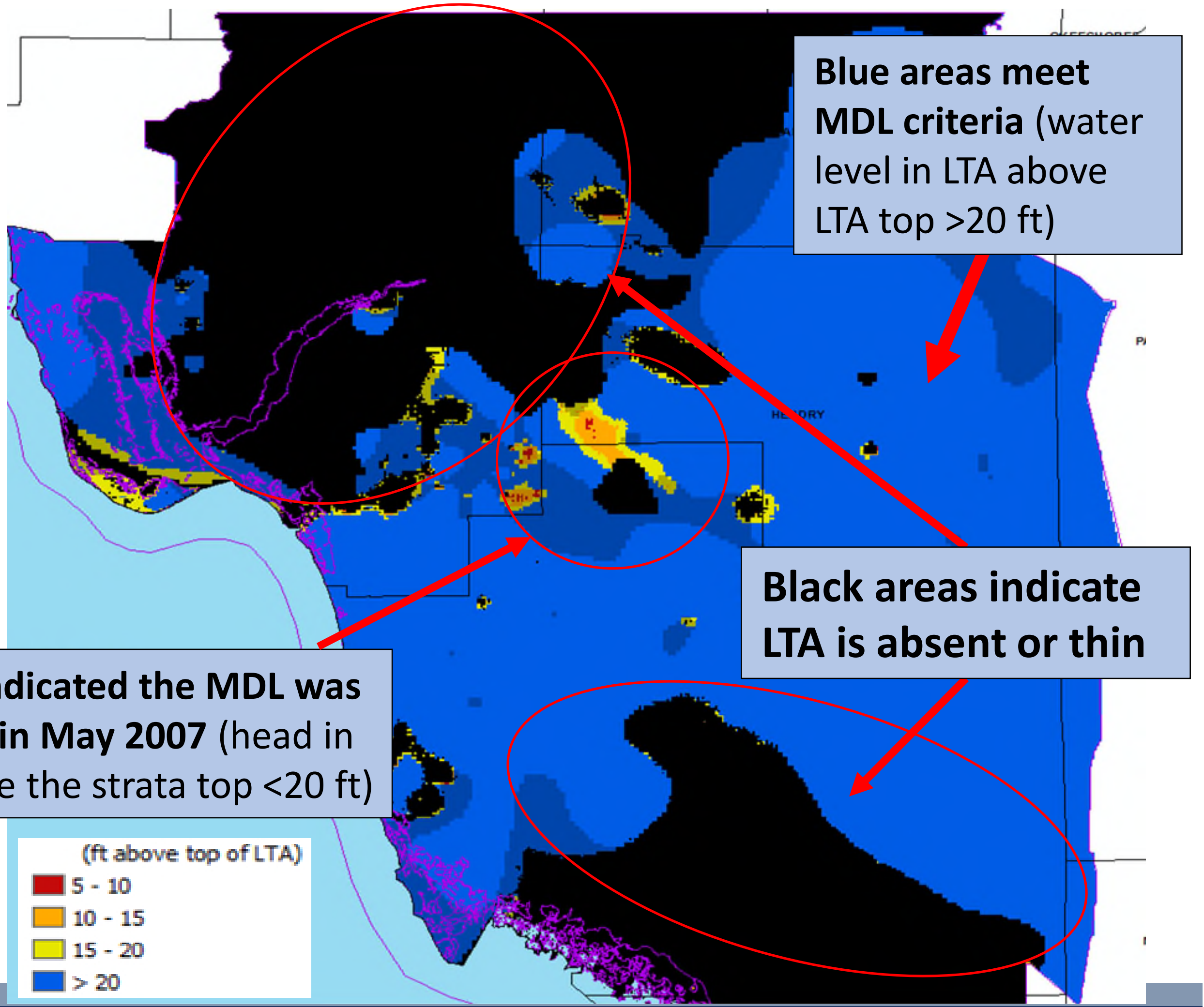


*1-in-10 drought year for LWC Planning Area for the period 1999-2012: 2007

2014 Lower Tamiami Aquifer MDL Analysis

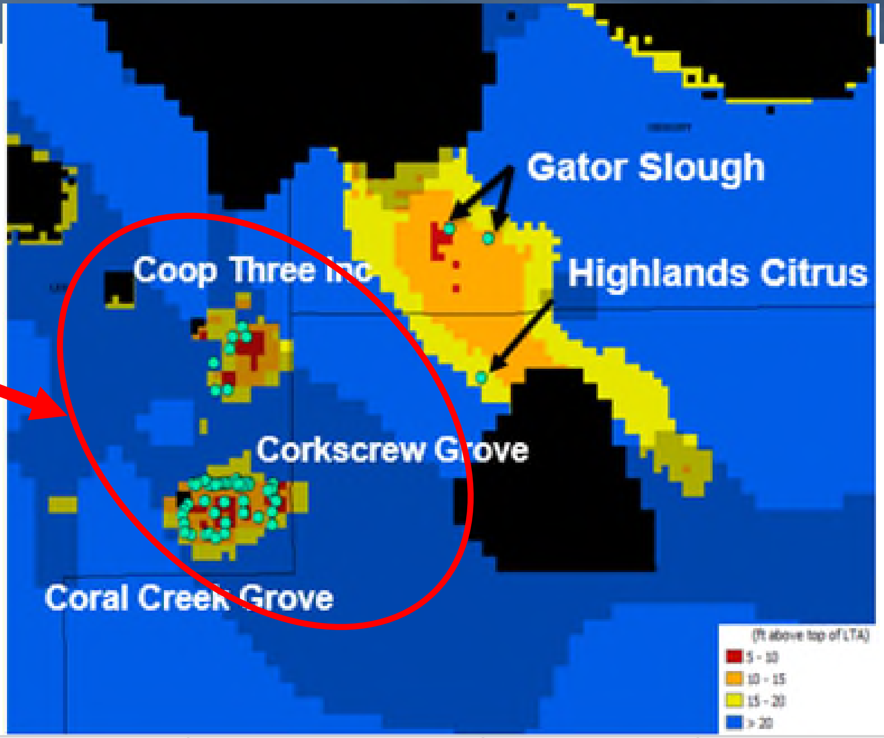
- Procedure
  1. Create raster surfaces of LTA top and simulated 1-in-10 condition LTA head (May 2007)
  2. Remove areas where LTA is absent or very thin
  3. Get the difference raster (LTA simulated head minus LTA top)
  4. Determine the area of potential violation

  (LTA simulated head – LTA top)< 20 ft



2014 RC Lower Tamiami MDL Analysis (cont.)

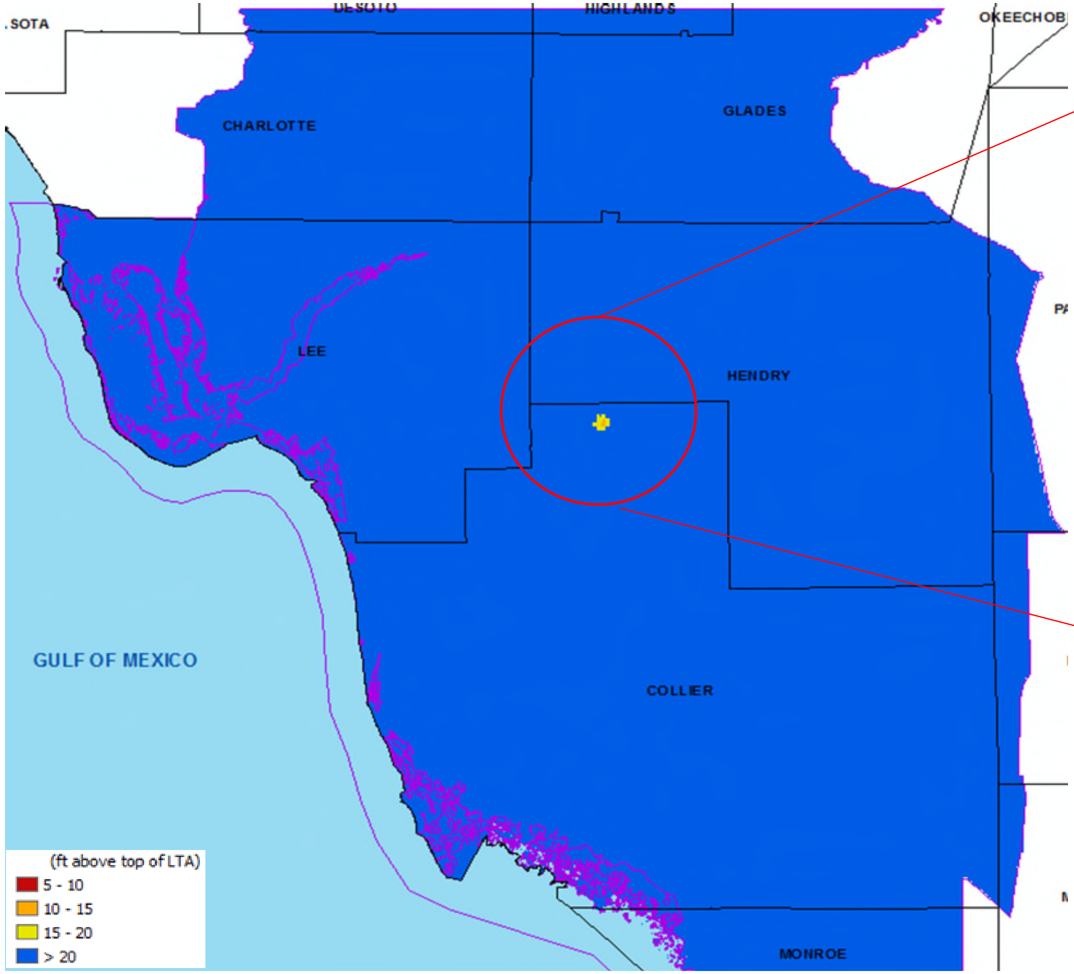
- Model simulated impacted areas have no confinement between Lower Tamiami and Water Table aquifers
  - Defining aquifer and MDL is difficult
- Monitor well data indicate that MDL was not violated during this period
- Associated with agricultural withdrawals
- Agricultural demands simulated with AFSIRS estimated due to absence of metered data
- What was actually pumped may differ from AFSIRS

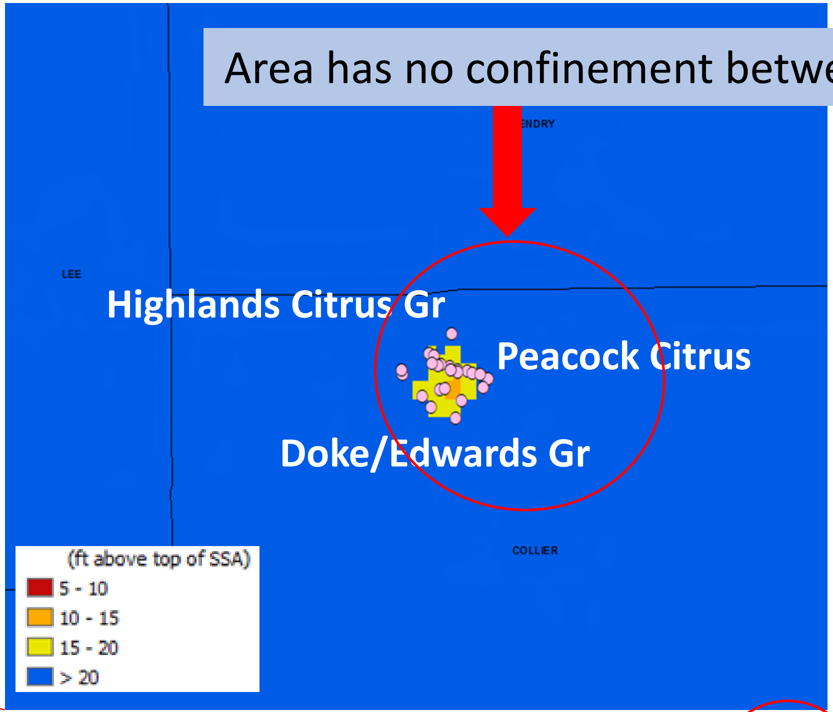


LTA MDL-Impacted AG Permits		From Permit	From Model	From Model	
Permit ID	Name	Permitted Allocation MGD	2014 Demand MGD	2040 Demand MGD	Model Layer
11-00262-W	Gator Slough	16.25	13.65	14.17	3,5,7
11-00094-W	Highlands Citrus Grove	7.70	4.32	3.74	1,3,5,7
36-00167-W	Coop Three Inc	7.54	1.81	1.69	1,3,5,7
36-00077-W	Corkscrew Grove	5.28	0.58	0.58	1,3,5,7
36-00201-W	Coral Creek Grove	0.80	0.21	0.47	1,3,5

AFSIRS = Agricultural Field Scale Irrigation Requirement Simulation

2014 RC Sandstone Aquifer MDL Analysis





Area has no confinement between SSA and LTA

SSA MDL-Impacted AG Permits		From Permit	From Model	From Model	
Permit ID	Name	Permitted Allocation MGD	2014 Demand MGD	2040 Demand MGD	Model Layer
11-00094-W	Highlands Citrus Grove	7.70	4.32	3.74	1,3,5,7
11-00172-W	Doke/Edwards Grove	1.56	1.02	1.02	5,7
11-00091-W	Peacock Citrus	0.52	0.19	0.19	5

- Decline in future demands
- No potential growth expected



Velocity Vector Analysis

Velocity Vector Analysis

- LWCSIM is not a density-dependent model
  - it cannot model saltwater intrusion
  - it cannot simulate salinity effects of sea level rise

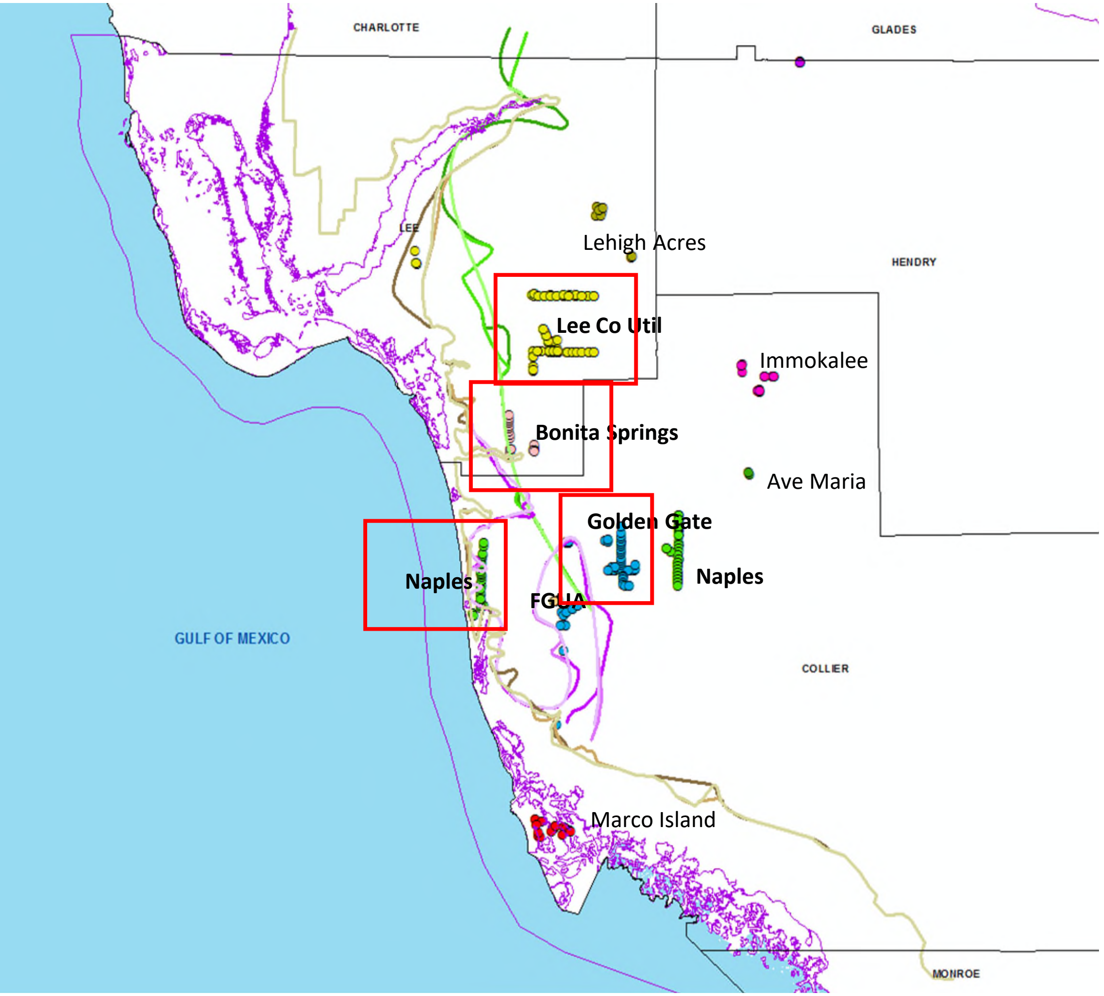
- Velocity vector direction can be an indication of movement of the saltwater interface
  - Interface positions are plotted as a reference to the wellfield locations only

Saltwater Interface & Public Water Supply Utilities

- Focus on public water supply utilities vulnerable to saltwater intrusion due to close proximity to the saltwater interface

Saltwater Interface (250 mg/L)

WTA	2009
	2014
	2019
LTA	2009
	2014
	2019
SSA	2009
	2014
	2019



Bonita Springs – Lower Tamiami Aquifer

Permittee	Aquifer	2014 (MGD)	2040 (MGD)	Increase
Bonita Springs	Lower Tamiami Aquifer	3.53	5.48	1.95

Saltwater Interface (LTA)

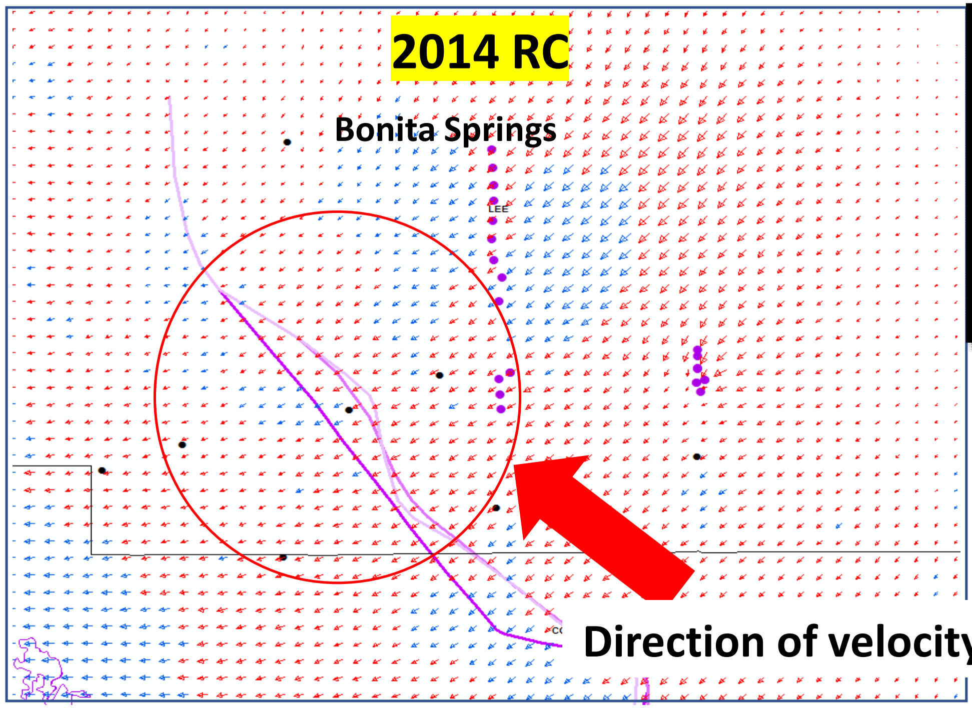
- 2009
- 2014
- 2019

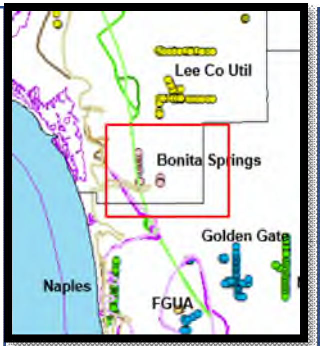
Upward

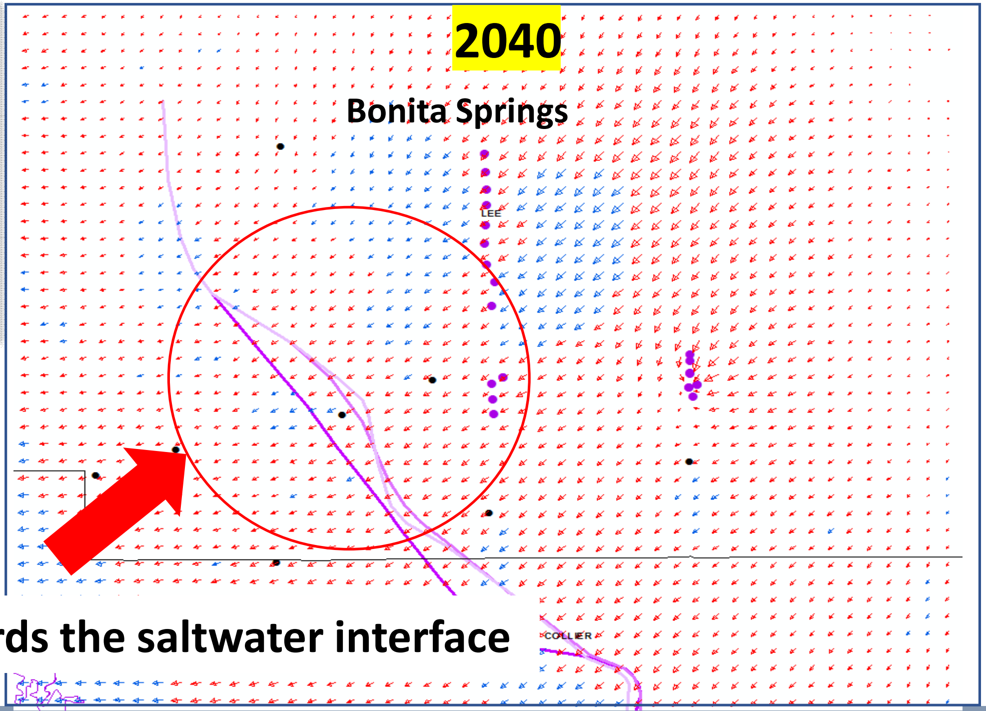
Downward

Velocity vectors in every model cell
Vector size proportional to velocity

- 2014: Direction of velocity vectors: towards the saltwater interface
- 2040: Conditions are almost the same







Direction of velocity vectors: towards the saltwater interface

Golden Gate – Lower Tamiami Aquifer

Permittee	Aquifer	2014 (MGD)	2040 (MGD)	Increase
Golden Gate	Lower Tamiami Aquifer	16.06	16.80	0.74

- 2014: Direction of velocity vectors: towards the saltwater interface
- 2040: Conditions are almost the same

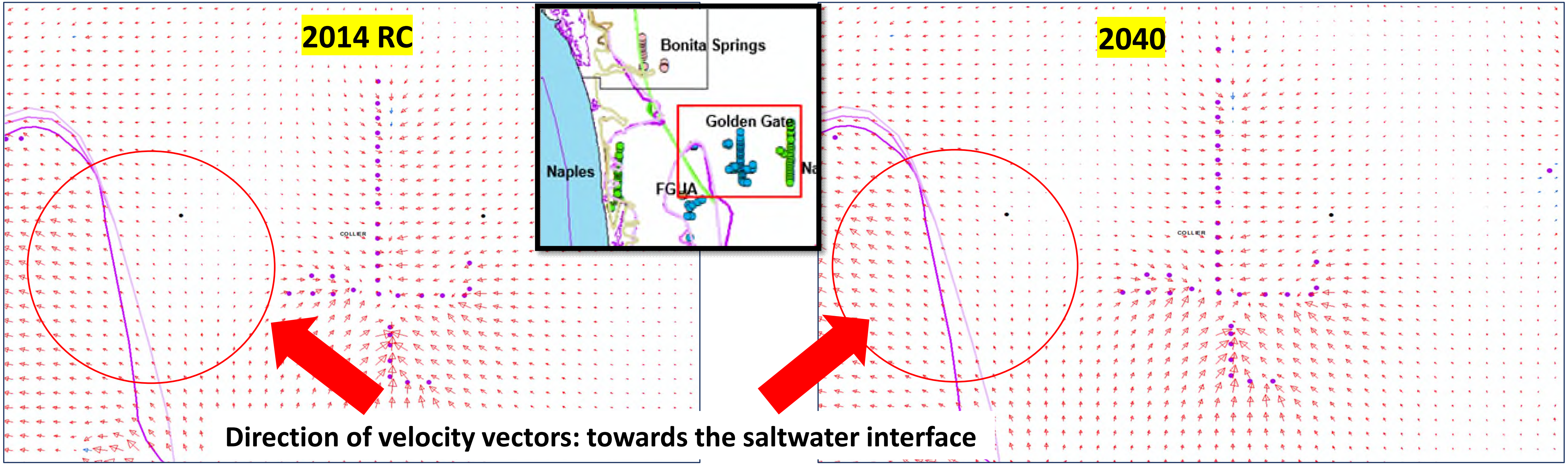
Saltwater Interface (LTA)

- 2009
- 2014
- 2019

Upward

Downward

Velocity vectors in every model cell
Vector size proportional to velocity



Direction of velocity vectors: towards the saltwater interface

City of Naples (Coastal) – Lower Tamiami Aquifer

Permit No	Permittee	Aquifer	2014 (MGD)	2040 (MGD)	Increase
11-00017-W	City of Naples	Lower Tamiami Aquifer	3.75	3.78	0.03

- 2014: Direction of velocity vectors: towards the saltwater interface
- 2040: Conditions are almost the same

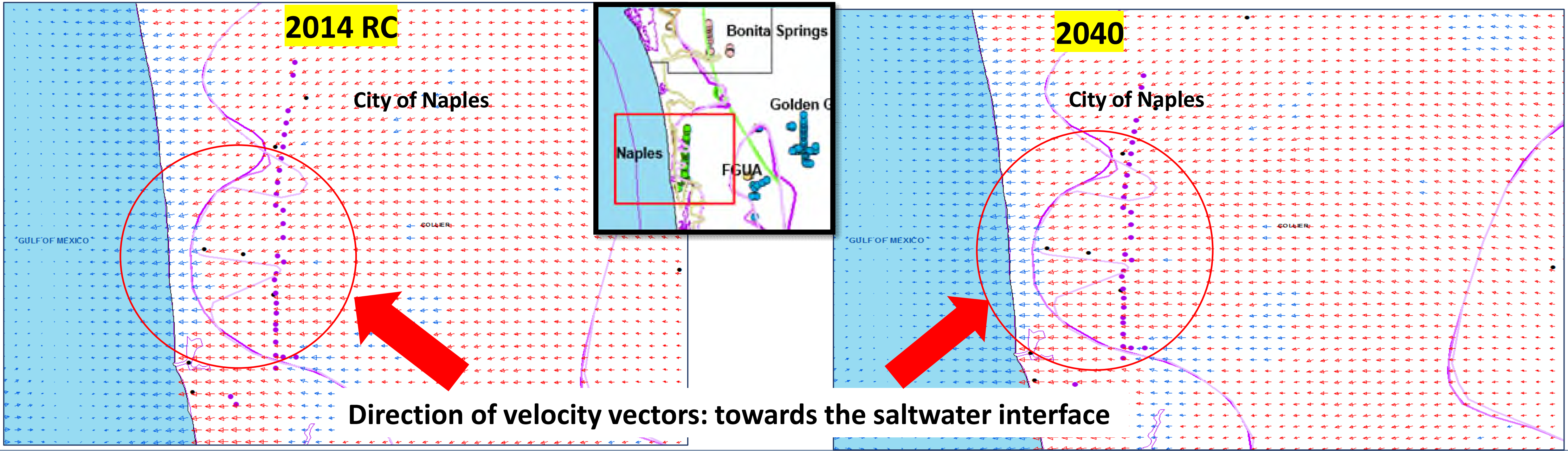
Saltwater Interface (LTA)

- 2009
- 2014
- 2019

Upward

Downward

Velocity vectors in every model cell
Vector size proportional to velocity
Maximum vector length = 2,000 ft

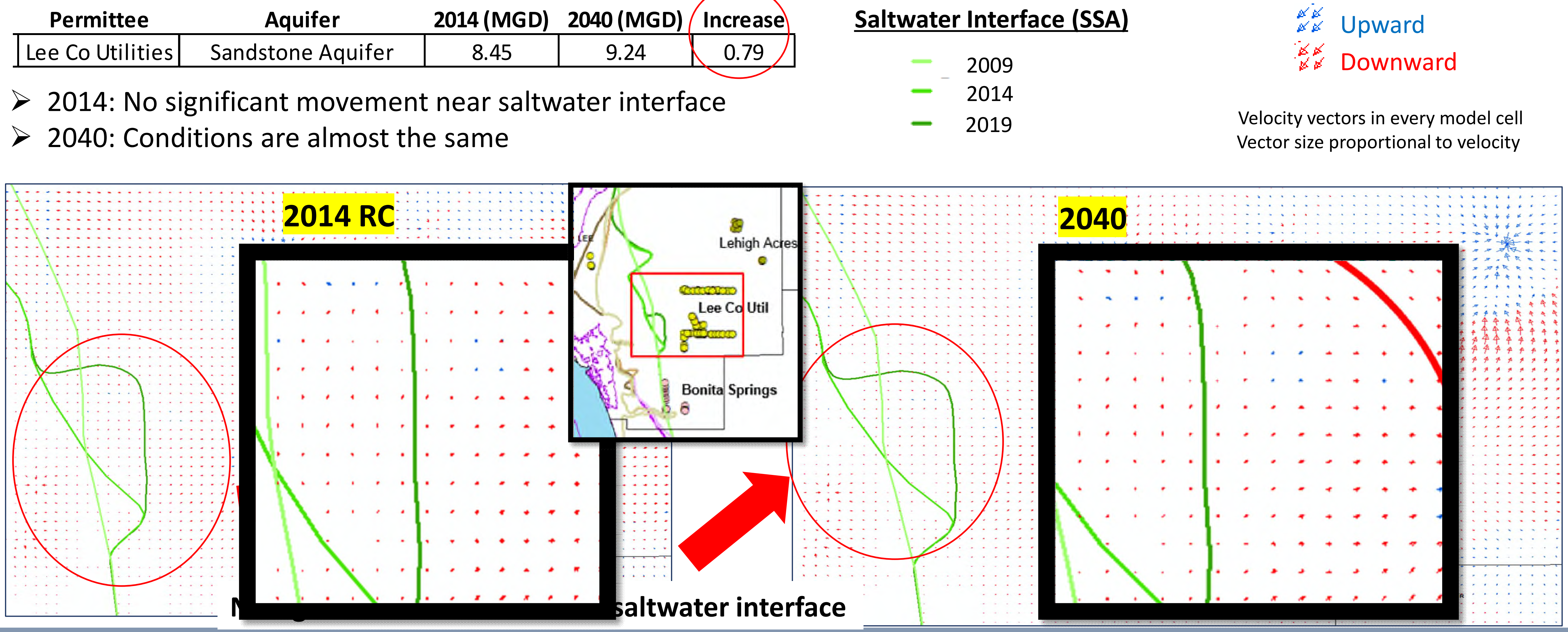


Direction of velocity vectors: towards the saltwater interface

Lee County Utilities – Sandstone Aquifer (Clastic)

Permittee	Aquifer	2014 (MGD)	2040 (MGD)	Increase
Lee Co Utilities	Sandstone Aquifer	8.45	9.24	0.79

- 2014: No significant movement near saltwater interface
- 2040: Conditions are almost the same



Lee County Utilities – Sandstone Aquifer (Carbonate)

Permittee	Aquifer	2014 (MGD)	2040 (MGD)	Increase
Lee Co Utilities	Sandstone Aquifer	8.45	9.24	0.79

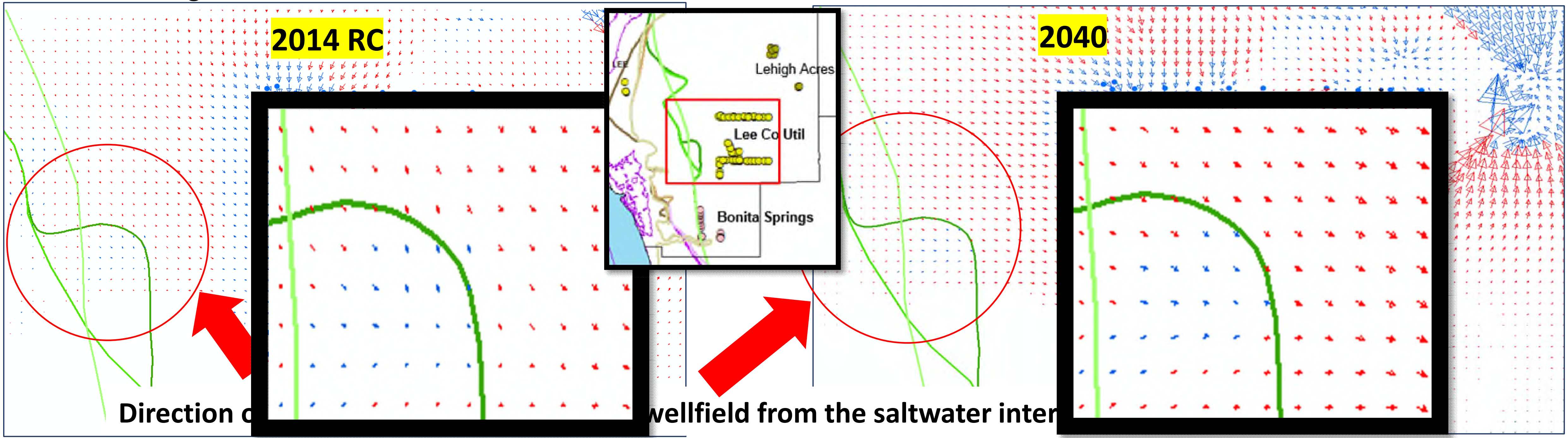
- 2014: Direction of velocity vectors towards the wellfield from the saltwater interface
- 2040: Slight increase in size of vectors

Saltwater Interface (SSA)

- 2009
- 2014
- 2019

Upward
Downward

Velocity vectors in every model cell
Vector size proportional to velocity



Modeling Conclusions

- LWCSIM – regional, calibrated, peer-reviewed model for the SAS/IAS in the Lower West Coast planning area
- Model indicates that 2040 demands can be met without undue impacts to existing groundwater resources and the natural system
  - Water levels rebounded in Cape Coral area of Mid-Hawthorn aquifer and southeastern Hendry County of Water Table, Lower Tamiami, and Sandstone aquifers due to decline in projected pumping
- Wetland analysis (pumps off scenarios)
  - Model calibrated to boundary conditions with pumping occurring, not to extreme condition of no pumps
  - Drainage and developments were not considered in this analysis
  - Some increases in wetland acreage associated with increase of 1 ft or more drawdown with 2040 demands
  - Water level rebounds in southeastern Hendry County, reduced current impacts in the future

Modeling Conclusions (cont.)

- MDL analysis
  - Limitation: Aquifer top elevations are interpolated values and may have a ±5 ft error
  - Limitation: Agriculture pumping rates were estimated using AFSIRS due to a lack of metered data
  - Lower Tamiami aquifer: Potentially vulnerable area has no confinement between Lower Tamiami and Water Table aquifers, makes interpretation and MDL analysis difficult (i.e., difficult to define the aquifer)
    - Monitor wells indicated MDL was not violated in 1-in-10 drought condition in May 2007
  - Sandstone aquifer: Potentially vulnerable area has no tight confinement between Sandstone and Lower Tamiami aquifers, makes interpretation and MDL analysis difficult (i.e., difficult to define the aquifer)
    - Decline in future demands and no potential growth in vulnerable area indicate the MDL violation is unlikely in the future
  - Mid Hawthorn aquifer: Model did not show any violation
  - Close attention needs to be paid to potentially vulnerable areas in LTA and SSA in the future

Modeling Conclusions (cont.)

- Saltwater intrusion analysis
  - LWCSIM is not a density-dependent model but potentially vulnerable areas for lateral intrusion can be identified using freshwater velocity vectors
  - Velocity vectors indicate no major lateral intrusion issues under current or proposed future conditions

Modeling Team

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Questions?

Model Layer Structure

[K_x Range - ft/day] *Based on APT/SC data* | [K_x Range - ft/day] *Based on SS PEST Calib*

Topo_NGVD29 — (Layer Surface elevation range, ft ngvd29) ➡ (127.149 to -7.881 ft ngvd29)

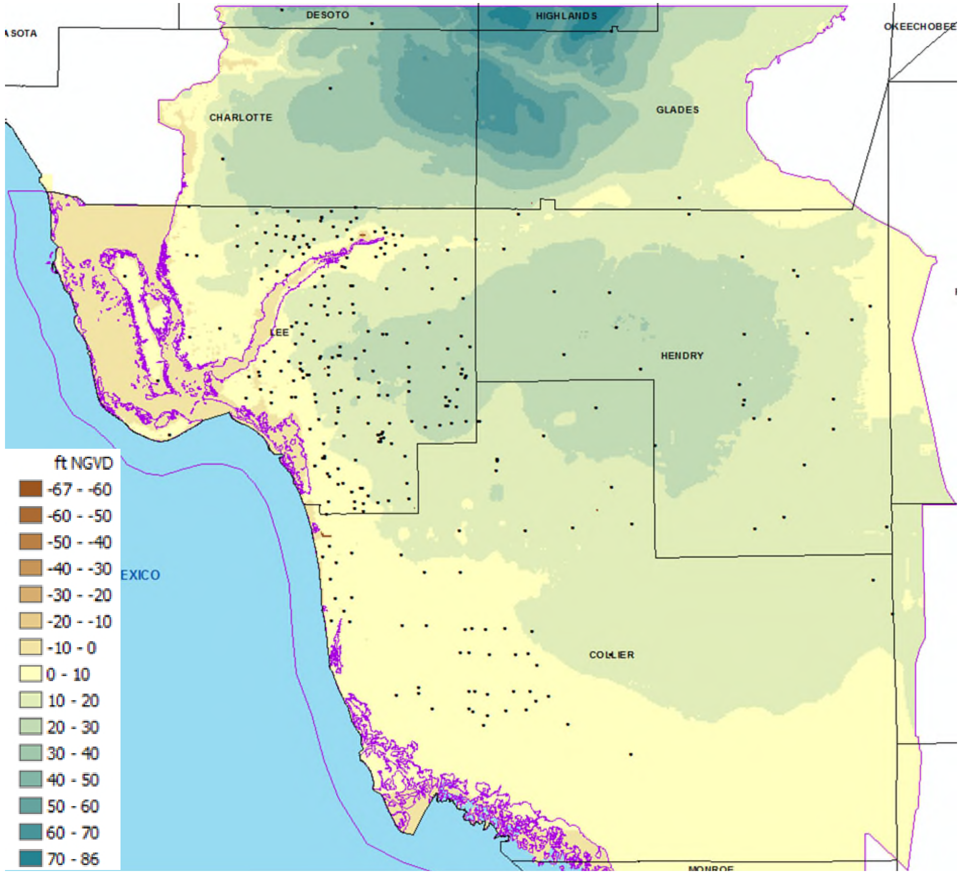
System	Layer	Surface	[K_x Range] APT/SC	[K_x Range] SS PEST Calib	Unit	Parameters	Layer surface elevation range
Surficial Aquifer System	L1	WT_BASE	[0.01 – 22,000] Avg = 915	[0.52 – 176,000] Avg = 1338	Water Table Aquifer (WTA)	Sy = 0.3, Por = 0.25, Ss range = 3.3e-6 – 0.257, Avg = 0.007	(51.4663 to -208.972 ft ngvd29)
Surficial Aquifer System	L2	LT_TOP	[0.061 - 16] Avg = 5.4	[0.118 - 36] Avg = 3.07	Tamiami Confining Unit (TCU)	Sy = 0.3, Ss = 0.00002, Por = 0.05	(50.7077 to -212.318ft ngvd29)
Surficial Aquifer System	L3	LT_BASE	[29.7 - 12000] Avg = 665	[0.53 – 17,300] Avg = 1530	Lower Tamiami Aquifer (LTA)	Sy = 0.3, Por = 0.25, Ss range = 1e-5 – 0.091, Avg = 0.0016	(50.7077 to -214.814 ft ngvd29)
Intermediate Aquifer System	L4	SA_TOP	[6.18 - 151] Avg = 44.2	[0.06 - 1150] Avg = 20.7	Upper Hawthorn Confining Unit (H1)	Sy = 0.3, Ss = 0.00003, Por = 0.05	(5.017 to -261.87 ft ngvd29)
Intermediate Aquifer System	L5	S2_BASE	[3.6 - 678] Avg = 87.2	[0.11 - 752] Avg = 30	Sandstone Aquifer – Clastic Zone (S2)	Sy = 0.3, Por = 0.25, Ss range = 2.5e-6 – 0.019, Avg = 1.1e-3	(-9.22 to -303.16 ft ngvd29)
Intermediate Aquifer System	L6	S1_TOP	[0.4 - 1151] Avg = 112.7	[0.12 - 1660] Avg = 44	Sandstone Aquifer – Confining Unit (SC)	Sy = 0.3, Ss = 0.00001, Por = 0.05	(-10.29 to -304.71 ft ngvd29)
Intermediate Aquifer System	L7	SA_BASE	[2 - 1459] Avg = 115	[0.16 - 2100] Avg = 52.8	Sandstone Aquifer – Carbonate Zone (S1)	Sy = 0.3, Por = 0.25, Ss range = 2.1e-6 – 0.002, Avg = 3.6e-4	(-22.19 to -362.99 ft ngvd29)
Intermediate Aquifer System	L8	HM_TOP	[5.48 - 1046] Avg = 135	[0.05 - 1810] Avg = 53.4	Mid-Hawthorn Confining Unit (H2)	Sy = 0.3, Ss = 0.0001, Por = 0.05	(-91.53 to -545.29 ft ngvd29)
Intermediate Aquifer System	L9	HM_BASE	[3.18 - 141] Avg = 31	[0.13 - 846] Avg = 79	Mid-Hawthorn Aquifer (MH)	Sy = 0.3, Por = 0.25, Ss range = 4e-5 – 4.7e-4, Avg = 1.2e-4	(-162.49 to -585.01 ft ngvd29)

Tamiami Formation (L1–L3)

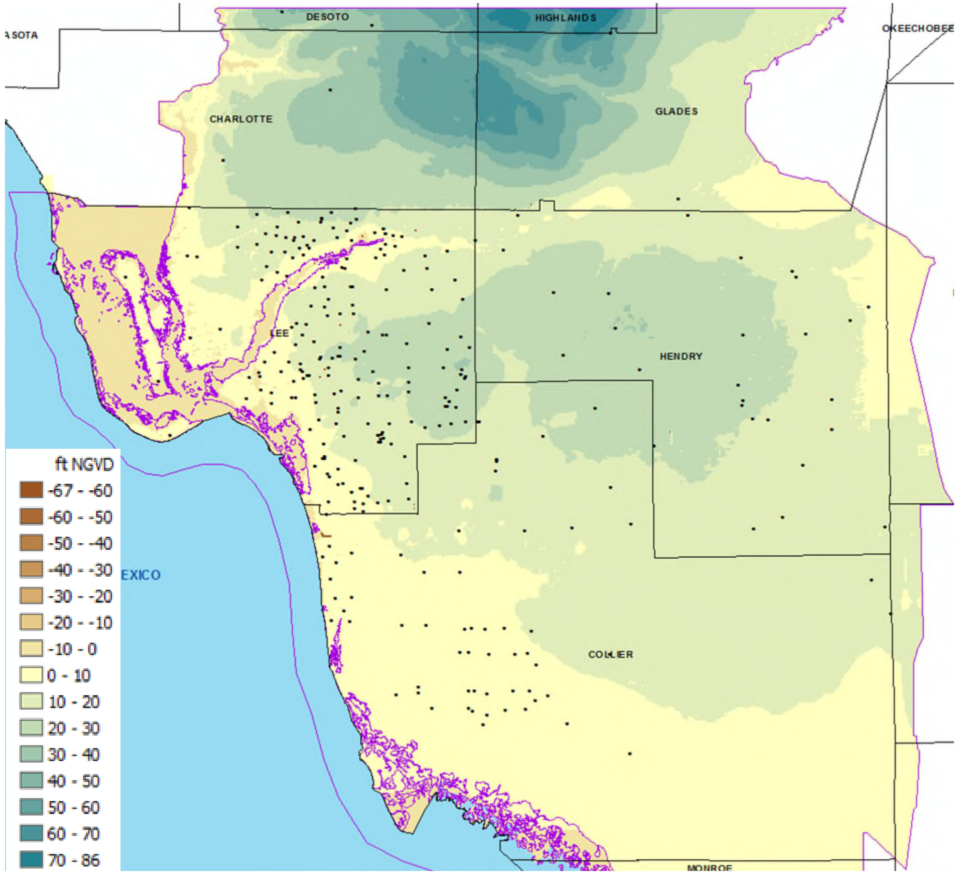
Hawthorn Group (L4–L9)

Simulated Average Annual Water Levels – Water Table Aquifer

2014



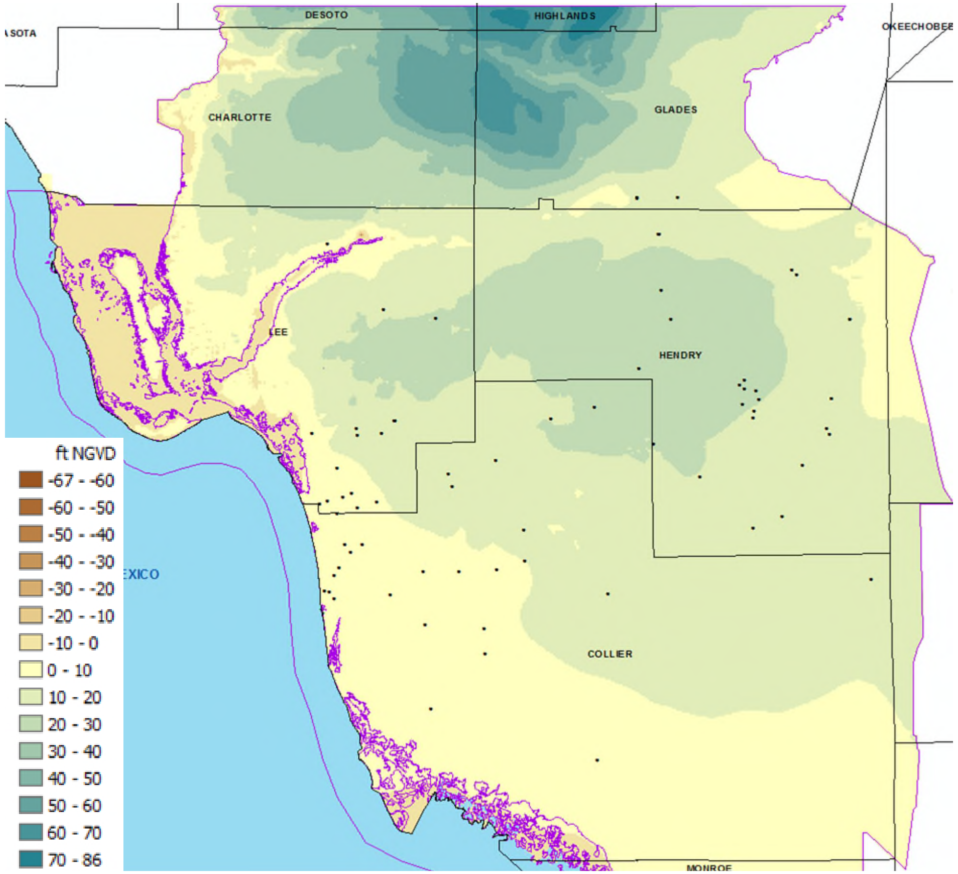
2040



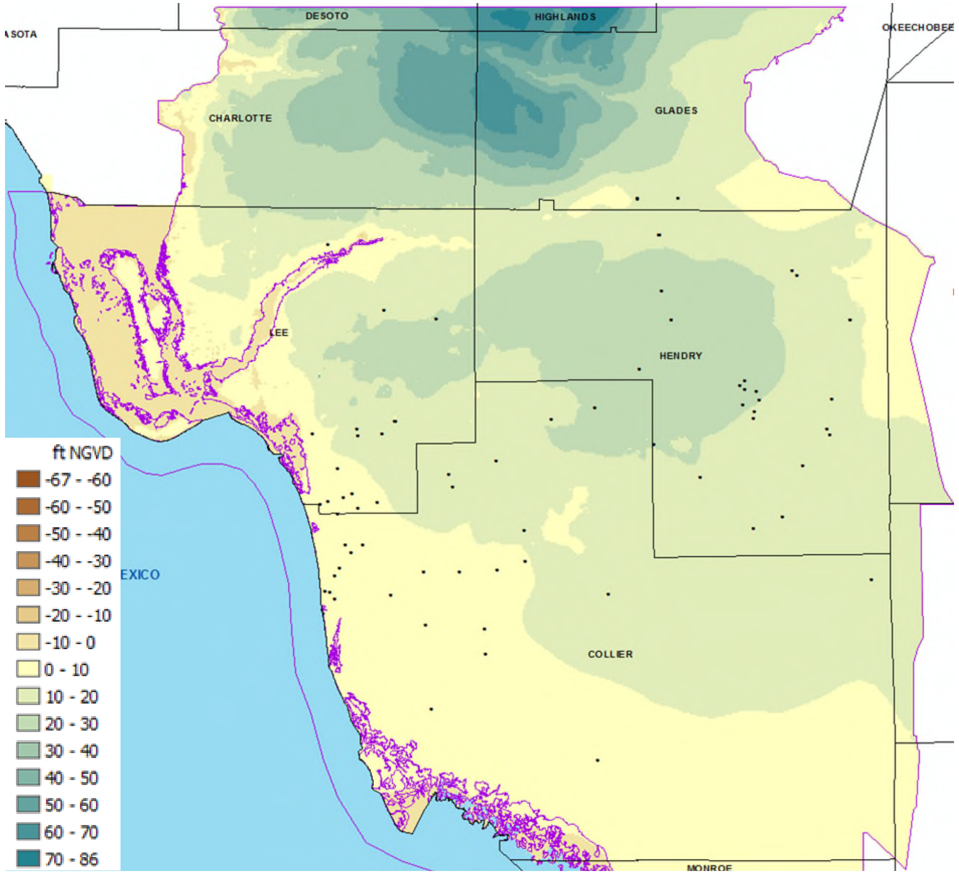
Black dots are head calibration targets

Simulated Average Annual Water Levels – Lower Tamiami Aquifer

2014



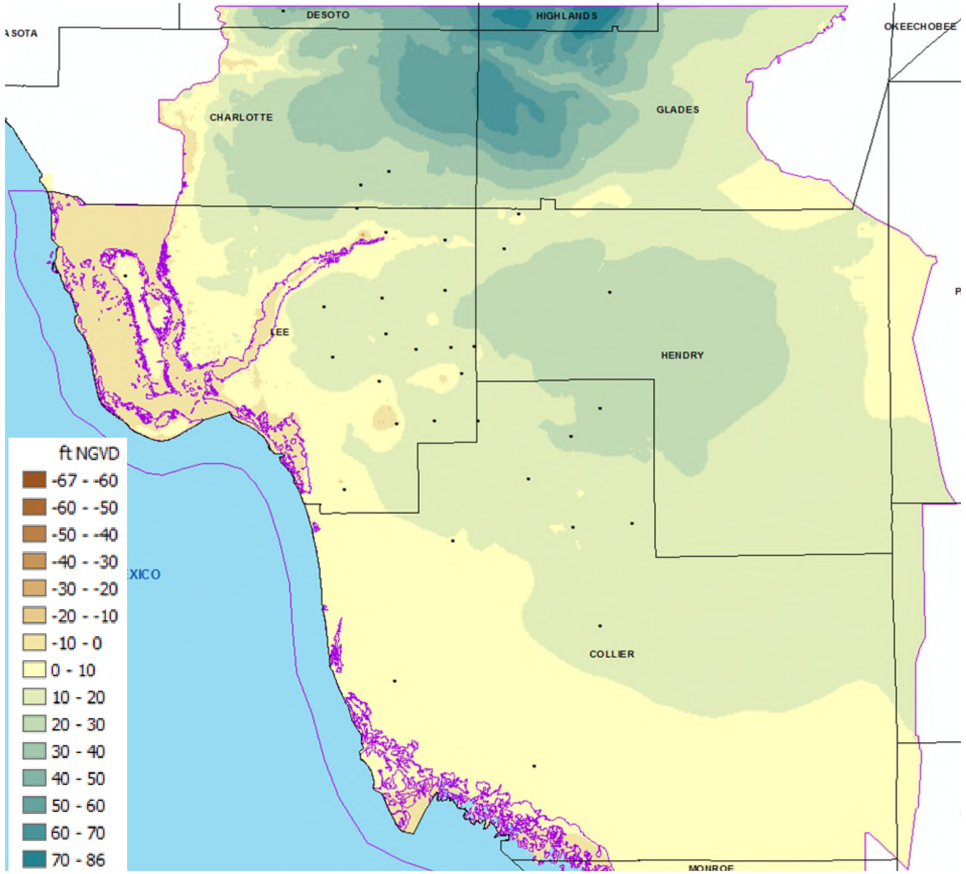
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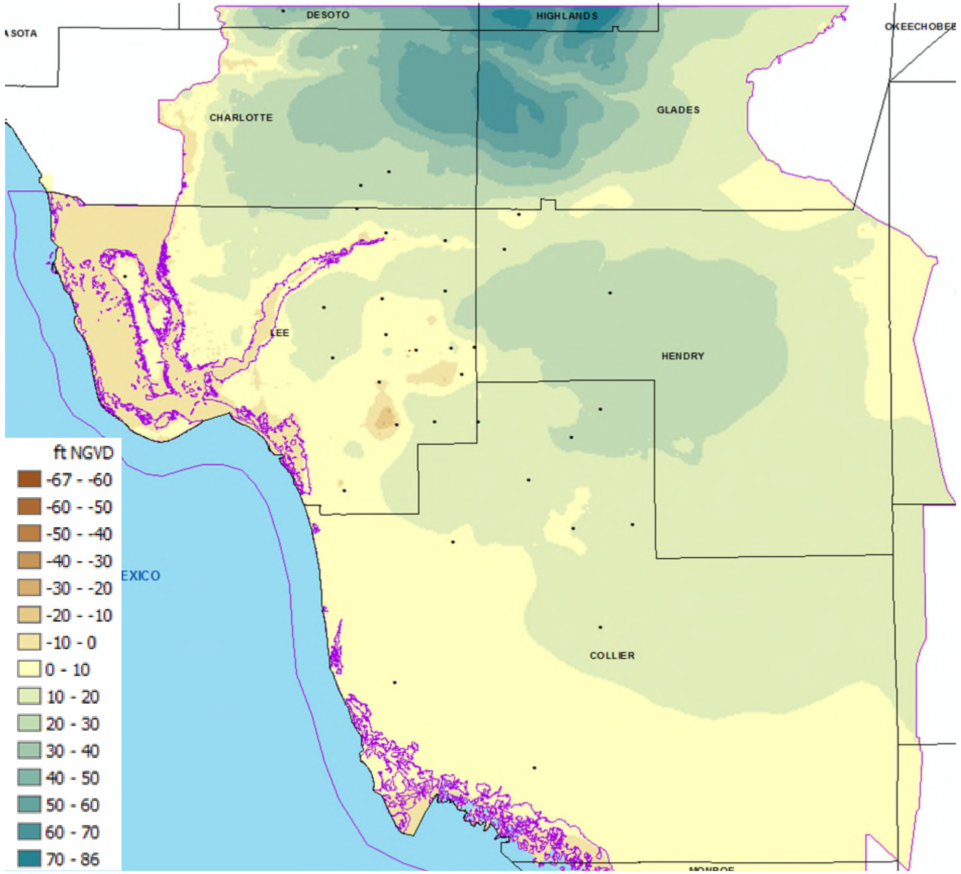
Black dots are head calibration targets

Simulated Average Annual Water Levels – Sandstone Aquifer (Clastic)

2014



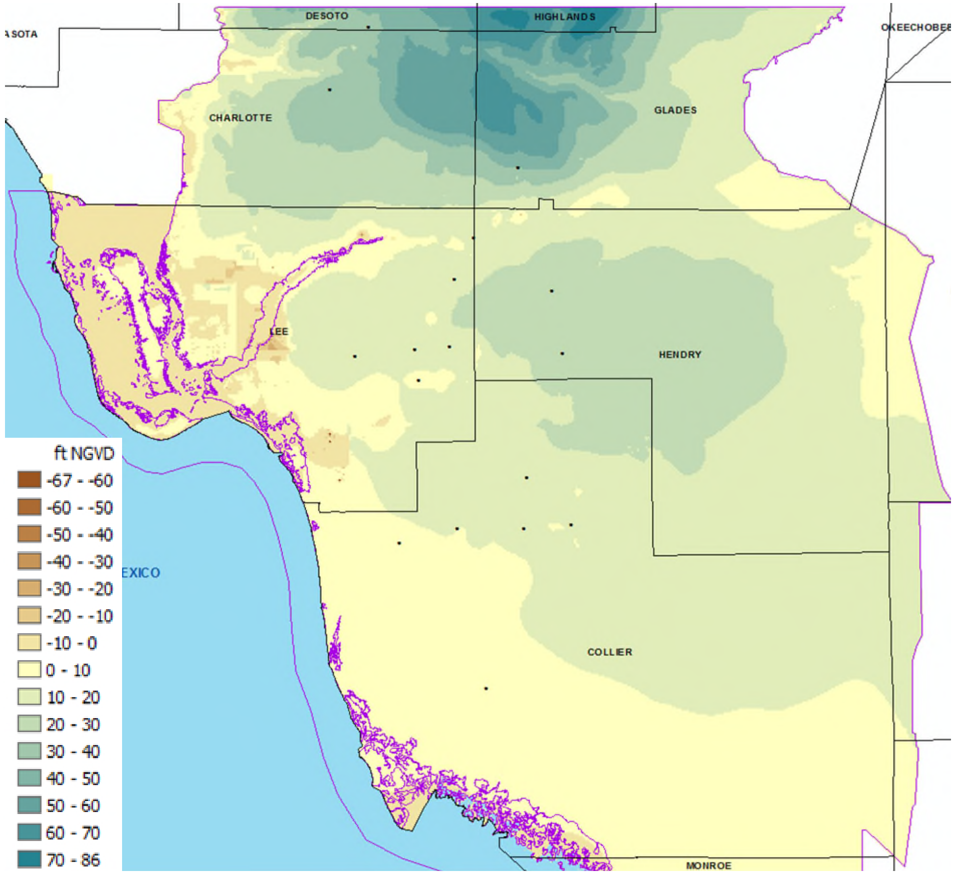
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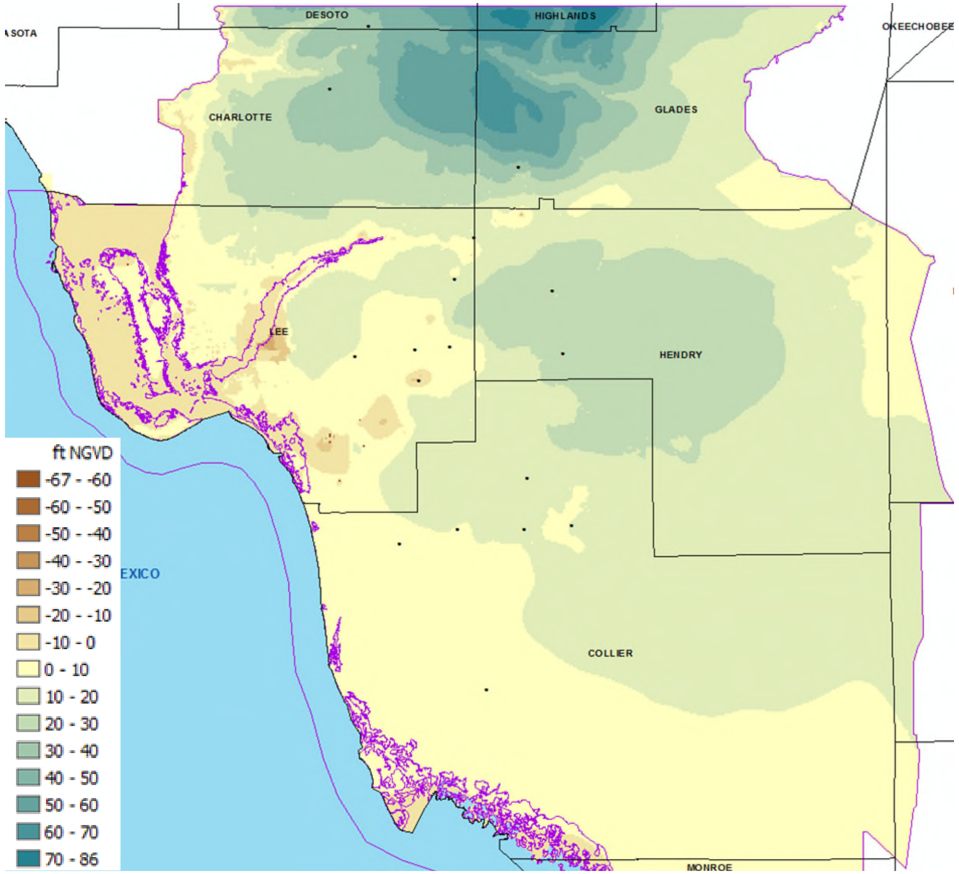
Black dots are head calibration targets

Simulated Average Annual Water Levels – Sandstone Aquifer (Carbonate)

2014



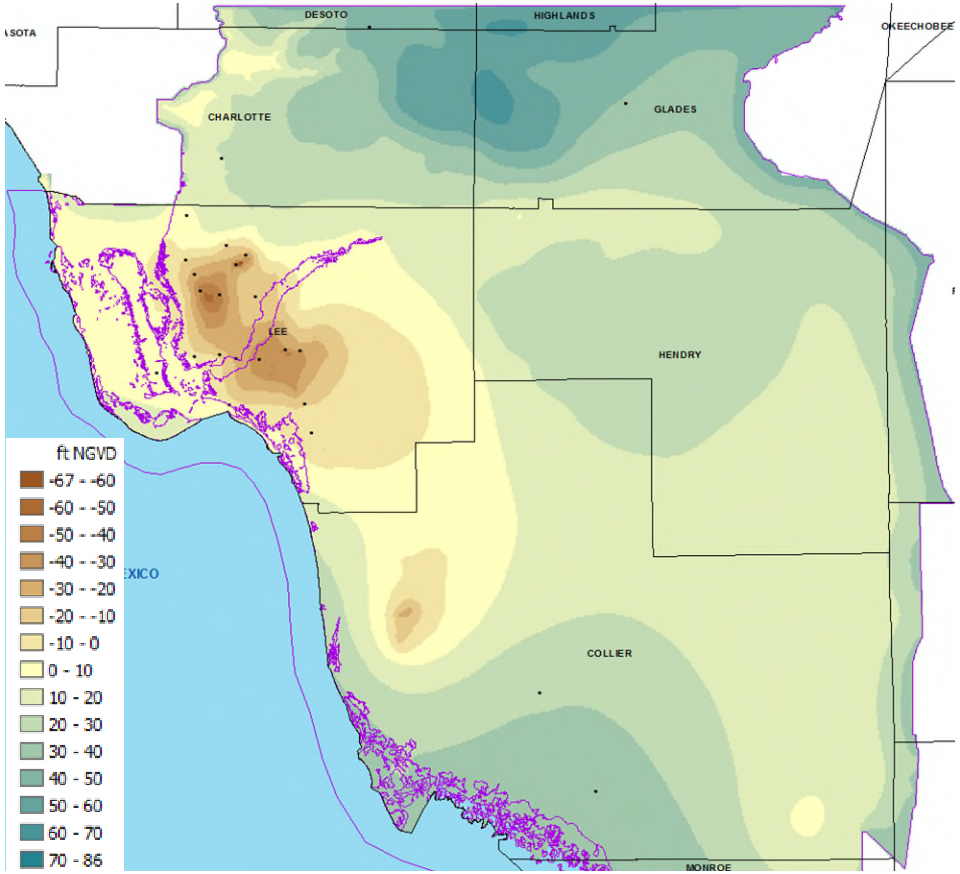
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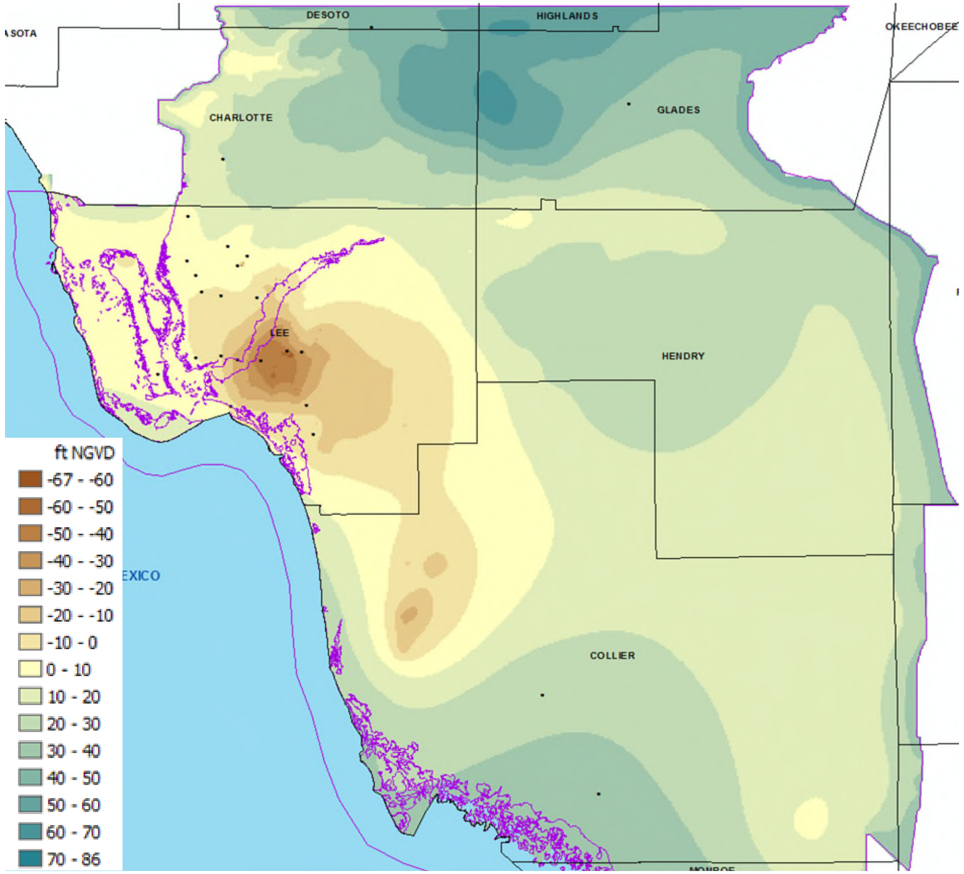
Black dots are head calibration targets

Simulated Average Annual Water Levels – Mid-Hawthorn Aquifer

2014



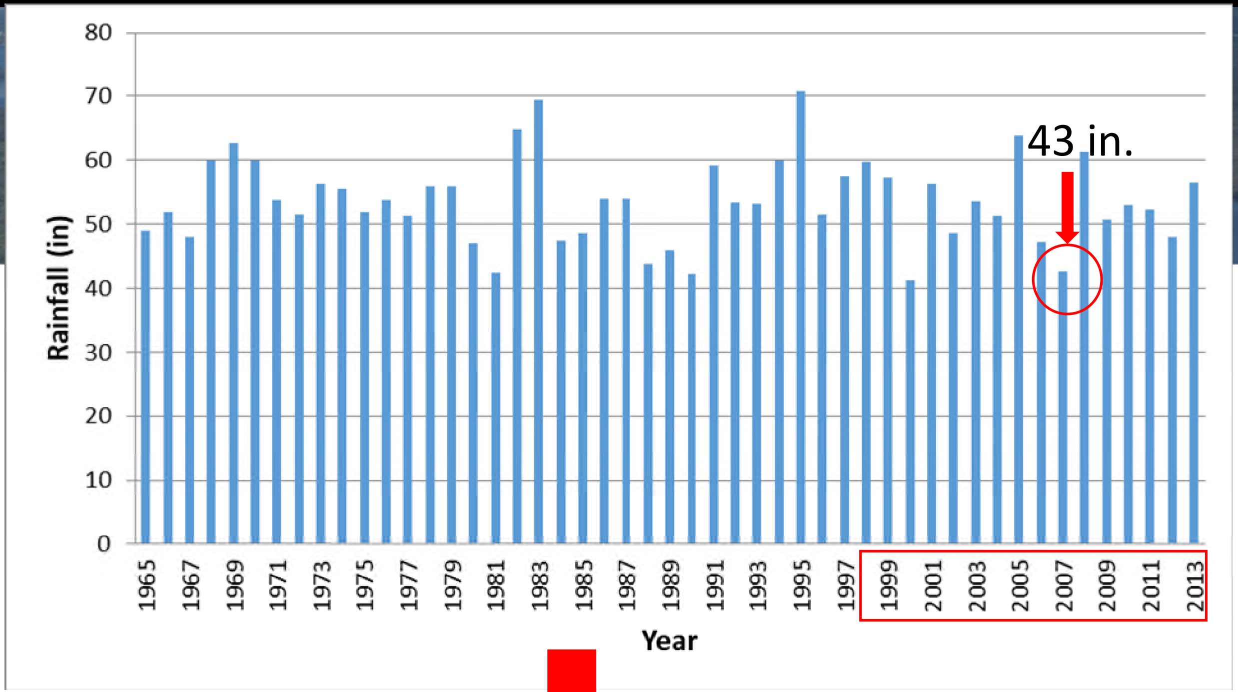
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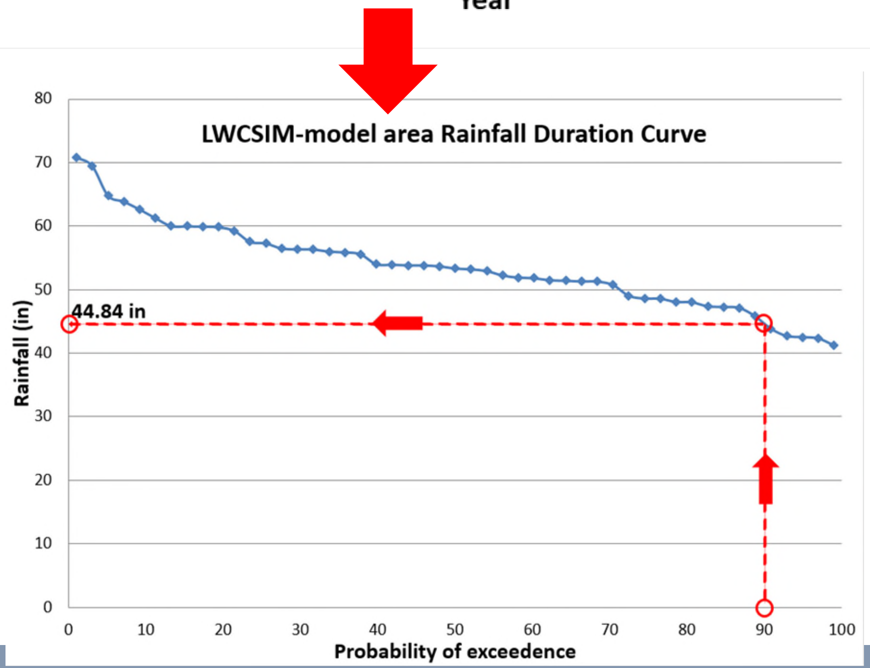


Black dots are head calibration targets

1-in-10 Year Drought

- 1-in-10 drought year was calculated based on rainfall data from 1965 to 2013
- 1-in-10 drought year rainfall ~45 inches
- 2007 had the closest rainfall (43 inches) to the 1-in-10 drought year within the model simulation period





Recreation/Landscape Wells

